Vol. XC. No. 2. March–April, 1953

GEOLOGICAL MAGAZINE

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STEPHEN AUSTIN & SONS, LTD.
1 FORE STREET, HERTFORD, HERTS

SUBSCRIPTION 32/6 PER ANNUM

GEOLOGICAL MAGAZINE

founded in 1864

by the late Dr. H. Woodward, F.R.S., with which

is incorporated

THE GEOLOGIST

(founded 1858)

Published every two months, price 32/6 per annum
(single numbers, 7/6).

Subscriptions for 1953, inquiries relating to back stock, advertising, etc., should be sent to Stephen Austin & Sons, Ltd., Fore Street, Hertford, Herts.

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GEOLOGICAL MAGAZINE

VOL. XC. No. 2. MARCH–APRIL, 1953

Issued 1st April, 1953.

New Evidence of Intra-Formational Piping at Two Separate Horizons in the Carboniferous Limestone (Dibunophyllum Zone) at South Cornelly, Glamorgan

By TREVOR M. THOMAS

ABSTRACT

Large-scale extractions from a limestone quarry immediately east of the village of South Cornelly have provided sections of the Dibunophyllum Zone (probably the top of D_1 Subzone) showing deep piping at two separate horizons. On the lower sides and floors of some of the larger pipes, the limestones and pseudo-breccias have been metasomatically replaced by a thin layer or by irregular pockets of haematite up to a foot in thickness. All the evidence points to two periods of emergence and sub-aerial erosion followed by lagoonal conditions with a Keuper-like environment when the irregularities of the underlying rock surface were filled with marl.

INTRODUCTION

AT several localities in the South Wales region variable bands of grey-green, red or purple marl, Keuper-like in general appearance, are associates of lagoon phases and more rarely of intra-formational breaks within the Carboniferous Limestone sequence. In the latter category the best known example is that at West Williamston on the Carew Anticline in South Pembrokeshire where the top of the Caninia Oolite has been honeycombed to a depth of about 8 feet by passages and irregular cavities filled with greenish clay mudstone continuous with the matrix of the overlying rubble bed (Strahan, 1914, p. 141). On the north crop of the main South Wales Coalfield the plane of the Intra-Avonian unconformity, coincident with the top of the Caninia Oolite in the east but successively transgressing lower zones to the west of the Vale of Neath, shows incursions of mottled purple and green marly clay succeeding the Oolite at such exposures as the old quarry immediately above the Tylerybont Limeworks at Pont-sticill (Robertson, 1933, p. 26) and Cwm quarries, Clydach Vale (Robertson, 1927).

Pronounced marl bands indicative of lagoon phases or unstable inshore conditions have been described as occurring within the Upper Seminula Zone (S_2) of Cwm Clydach in south-east Brecknockshire (Robertson, 1927), and towards the top of the Lower Dibunophyllum Zone (D_1) near Maes Dulais, central Carmarthenshire (George,

1927, p. 57). In the first example, sections at Cwm quarry, Llanelly quarry, and in the Clydach river show a thickness variation of 10 to 20 feet of green, yellow and purple marly clay with nodules of ironstone. Near Maes Dulais, exposures in a stream bed reveal up to 30 feet of red and buff-coloured marls.

The two main bands of brick-red-brown and grey-blue marls to be described as forming part of the sections displayed at Gaen's quarry, South Cornelly, show pipes ranging up to a maximum depth and diameter of about 30 to 35 and 100 feet respectively. These bands, with their rapid and somewhat startling increases in thickness in the numerous pipes, are given great clarity of outline by the fact that they are both overlain and underlain by massive pseudobreccias or crystalline limestones with a very low northward dip.

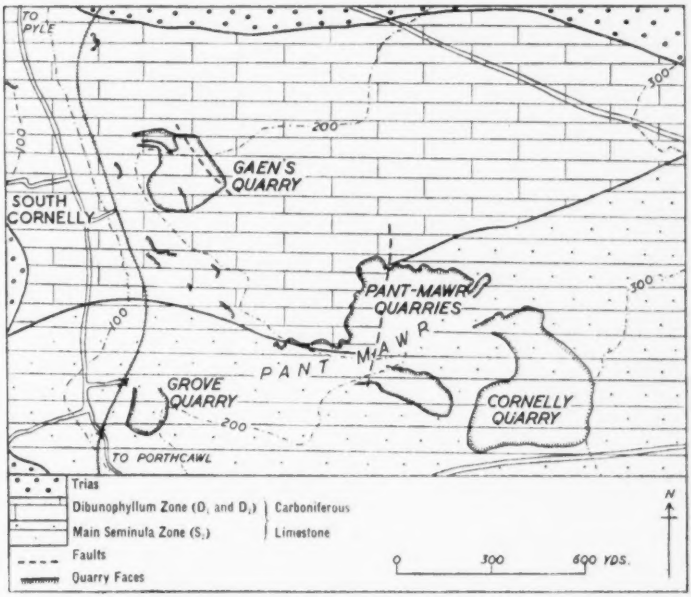
General Description of the South Cornelly Area

To the east of South Cornelly the main Carboniferous Limestone outcrop has an approximate west–east strike, and in its south to north width of 2 miles shows a relatively simple structure, forming as it does the northern limb of an elongated anticline with eastward pitch (the Candleston Anticline). Successively newer zones thus outcrop in a northward direction. In the latitude of South Cornelly and extending from the northern limit of the Limestone to the northern edge of Pant Mawr, a well defined dry valley leading westward from Stormy Down, beds of the Dibunophyllum Zone (D_1 and D_2) outcrop. These are more than 600 feet in total thickness, their full extent not being known owing to the Trias overlap to the north. Massive limestones with much pseudobreccia are characteristic of the zone as a whole, the latter being the predominant rock type. The upper subzone is less pseudobrecciated than the lower, but otherwise there is no great lithological change. Faunal differentiation of the two subzones is most difficult, and has not yet been attempted. Southward from Pant Mawr and as far as the small gully known as Pant-y-Rhyll some 800 feet of the Main Seminula Zone (S_2) are exposed. As in other parts of South Wales this zone is divisible lithologically into an upper portion constituting a lagoon phase with coarse oolites, pisolites, algal limestones and calcitic mudstones, and a lower portion with standard limestones and the thick bed of oolite, the Seminula Oolite (George, 1933).

The outlying Carboniferous Limestone outcrop of the Porthcawl area with its approximately horizontal beds has also been assigned to the Dibunophyllum Zone. An interrupted coastal section displays the typical pseudobreccias which in places approach true breccias in that the individual fragments are detachable.

Natural exposures have been rendered insignificant by the sections

provided by extensive limestone quarrying operations concentrated in the South Cornelly–Stormy Down area. It is true to say that such activity is on a greater scale here than in any similar-sized area in South Wales. The majority of these quarries, ranging from Grove in the west through Pant Mawr and Cornelly to the various quarries on Stormy Down, are aligned along the Main Seminula Zone in which the Oolite is the most valuable stone particularly for fluxing purposes. Rock extraction in the past from the Dibunophyllum Zone has, in contrast, been on a rather limited scale and of a scattered nature. At the time of the detailed stratigraphical investigation of this area by Professor T. N. George (1933) the best section available was



TEXT-FIG. 1.—Map of the South Cornelly area. (Zonal subdivision of Carboniferous Limestone partly based on T. N. George, 1933.)

at the former South Cornelly Limeworks where some 120 feet of the mid-portion of the zone were exposed. A ferruginous red marl band up to 3 feet thick was described as being interstratified with massive crinoidal and oolitic limestones. The increased excavation of Gaen's quarry, directly east of and overlooking South Cornelly, in the past 15 years has more than compensated the previous restricted nature of exposures, natural and quarried. Of pit form, roughly rectangular in outline and with four faces each averaging approximately 175 yards

in length and 30 to 50 feet high, it has brought to light structures totally unexpected from the evidence of older exposures immediately to the east and south.

Details of Gaen's Quarry

A low north-north-westerly dip of about 5 degrees coupled with a rather limited depth of excavation have revealed a vertical sequence rather less than one might have expected in a quarry of this lateral extent. Reading downward the general succession is as follows :—

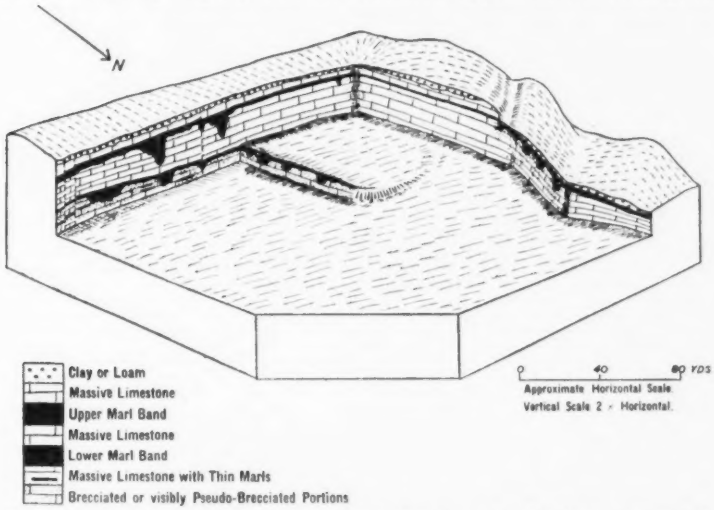
	Thickness Variation.
Overburden . . . . . Loam, clay, and rubbly subsoil.	2–15 feet (maximum attained in a few irregular pipes).
Massive Limestone . . . . . Includes some pseudobreccia.	Up to 30 feet exposed.
Upper Marl Band . . . . . Brick red-brown and blue-grey marls weathering to a purple hue. (Normally 2–4 feet thick.)	1–35 feet (upper figure represents a calculated maximum.)
Massive Crystalline Grey Limestone and Pseudobreccia . . . . . (Normally 25–30 feet thick.)	0–30 feet
Lower Marl Band . . . . . Brick red-brown, blue-grey and purple marls passing into rubbly seams where attenuated. (Normally 1–2 feet thick.)	6 inches–18 feet.
Massive Grey Limestone and Pseudobreccia . Bedding planes in the upper 10 feet contain impersistent seams up to a foot thick of brecciated rubble with grey marl infillings.	Up to 20 feet exposed.

Although there is an eastward deviation from a true north to south alignment the four faces may be appropriately termed northern, western, southern, and eastern respectively. The northern and southern faces approximate to true strike sections, and the western and eastern faces to dip sections. A lower cut or gallery to a depth of some 25 to 30 feet is being advanced south-eastward across the floor of the main quarry from the north-western corner.

The upper marl band is exposed in all four faces and along their entire overall length of some 700 yards. Its normal thickness is 2 to 4 feet, but it is piped on all four faces. At present a dozen pipes can be recognized in which the marl has its thickness increased to more than 6 feet. A rather higher number of corrugations is evident on the top of the underlying beds in the intervening stretches and in the downfolds of which the marl increases to thicknesses of 4 to 6 feet over lateral distances up to 8 or 10 feet. In plan these pipes are roughly oval or irregularly circular, and are thus more localized in their effects than the discontinuous channels or elongated basins recently described as affecting the Lincolnshire Limestone of

Northamptonshire and attributed to submarine erosion (Taylor, 1947, p. 246). The most spectacular pipes are on the southern and northern faces.

Some 40 yards of section in the mid portion of the southern face shows two major pipes, the more westerly of which has a maximum width of 40 feet and a maximum depth of 20 feet. The lower half of this latter pipe has very steep and smooth sides which do not appear to be controlled by major joints. In section its upper half has been given



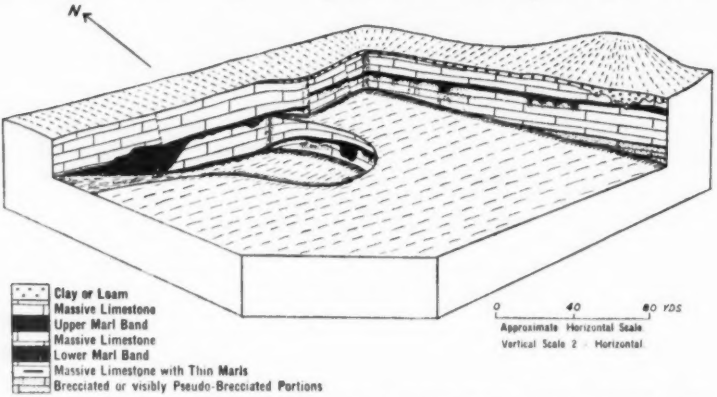
TEXT-FIG. 2.—Simplified block diagram showing the Sections exposed in the southern and western faces of Gaen's Quarry, South Cornelly (as at 1st April, 1952). (It should be noted that the sections exposed in the southern face in particular are liable to rapid change with pipes of marl being worked through and new ones encountered.)

a very irregular profile by relatively flat benches and minor pipes contained within the one main feature. The benches, when cleared of marl, reveal irregular hollows up to 4 feet across and 18 inches in depth. The other major pipe immediately to the east is not of such a composite nature, but has a width of 20 to 25 feet and a maximum depth approaching 25 feet. The walls of this second pipe are again very smooth ; they bear no coating of stalagmite, but have been stained a yellow brown by contact with the overlying marls.

The marls within these pipes as well as in the intervening stretches are generally striped brick red-brown and blue-grey in colour. Individual stripes range from a few millimetres to more than an inch in thickness and may be highly contorted. Brick red-brown is the dominant colour. When fresh some of the marl has a massive appearance. It, however, crumbles rapidly on exposure to small

fragments, there being no lines of lamination or inherent weakness parallel to the striping. On weathering, its admixture of contrasting colouring gives it a purplish hue. Adhering to the base and lower walls of these pipes are irregular patches of soft haematite 1 to 6 inches thick. This is normally of earthy consistency.

The largest pipe discovered to date is to be seen in the western half of the northern face. This has been bisected by the new roadway leading down to the lower gallery so that its threefold dimensions can be gauged with some measure of accuracy. These have been calculated as : length—100 feet, width—80 feet, and depth—30 to



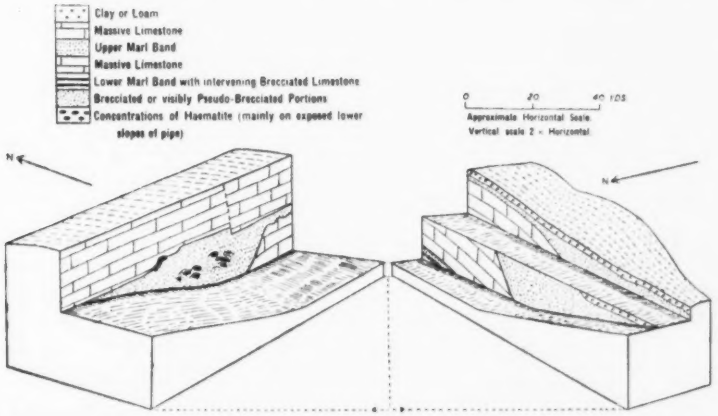
TEXT-FIG. 3.—Simplified block diagram showing the sections exposed in the northern and eastern faces and the advancing lower gallery of Gaen's Quarry, South Cornelly (as at 1st April, 1952).

35 feet. The marl here is overlain by 20 to 25 feet of massive well-jointed limestone which has been folded into a very gentle arch so that the top of the underlying marl has assumed a slight upward convexity with a sharp rise of 3 feet on the west and one of 4 feet affected by a small fault on the east. Other evidence of later compaction and internal movement of marl within or near this feature has been afforded by the metasomatic replacement of some of the overlying limestone by a thin film of haematite, and the relative concentration of this mineral on broken surfaces of marl in the top foot of that deposit. Part of the marl has assumed a sooty grey-black and dirty grey-green colouring on weathering. The base of this pipe is rather irregular and hummocky, and shows pseudobreccia with variable patches of haematite up to a foot thick. The latter is considerably harder than that found beneath the marl on the southern face. Analyses of typical samples indicate some 40 to 45 per cent iron. In an easterly direction this pipe ends rather abruptly, its underlying contact with the limestone sloping upward at some 30 to 40 degrees without any inter-

vening brecciated or visibly-pseudobrecciated layer. The overlying massive limestones are traversed by numerous thin veins of calcite, largely utilizing joint planes. Throughout their full vertical extent these veins are stained with haematite, and where well-developed dog-tooth crystals are present this mineral forms a thin coating on individual crystal faces. This staining is suggestive of a further marl band higher in the sequence, but the possibility of a former Triassic overlap must not be overlooked.

In the western and eastern faces pipes in the upper marl band reach a maximum depth of 10 feet and a slightly greater width. They show steep or near-vertical sides and a flattish base, and so are pothole-like in general appearance.

The upper marl band becomes very attenuated in the southern half of the western face where in places it is slightly less than a foot in



TEXT-FIG. 4.—Simplified block diagrams showing in more detail the large pipe or cavity filled with marl and exposed in the northern face and lower gallery of Gaen's Quarry, South Cornelly (as at 1st April, 1952).

thickness. Here it is in the nature of a rubbly seam with grey-green marl enclosing broken rock of somewhat flaggy nature.

Except where reduced by these downward projections of the upper marl band the underlying limestone is normally 25 to 30 feet thick. It is massive in habit and rarely displays well defined stratification. The bulk of this rock is a crystalline limestone in which segregations of calcite in minor rhombohedra and averaging 1 inch in diameter are widely dispersed in a ground mass of finely broken calcite with irregular incursions of dolomite in the vicinity of joints. Upward and on approaching the marl band this grades in places into pseudobreccia. The latter is very conspicuous towards the base of the more flat-

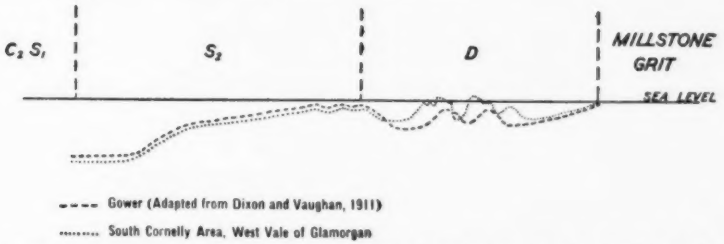
bottomed of the medium-sized pipes. Pseudobrecciated rock may extend downward along major joints for depths of 10 to 15 feet below the marl, and in places pass into true breccias in small cavities where the pebbly constituents can be detached from the binding grey-green marly matrix. Fossils are not too conspicuous in these massive limestones or pseudobreccias. *Productus corrugato-hemisphericus*, *Productus giganteus*, and species of *Dibunophyllum* and *Lithostrotion* have been recognized.

The lower marl band is not so extensively exposed as the top marl band. It is to be seen to best advantage in the southern face, the eastern face of the lower gallery and in a low bank left in the south-central part of the main gallery. Lithological characters are generally identical to those of the upper marl, but the average thickness is now only 1 to 2 feet. Eight pipes in which the thickness of marl is increased to 5 feet or more can be seen at present. Minor corrugations on the floor of this marl band are not nearly so frequent as was the case with the upper marl band.

The southern face shows two major pipes of greatly contrasting form. Towards the centre of this face is a pipe some 20 feet across and 10 feet deep with steep sides and a relatively flat base. This feature is stuated almost directly below a major pipe previously described with the upper marl. The second major pipe, located near the south-eastern corner of the quarry, has a diameter of 30 to 35 feet, a maximum depth of 8 to 10 feet, and a very pitted base. The lateral extensions of the marl band from both these pipes show a rapid thinning to 1 to 2 feet and an associated change in lithology and colour to a grey-green marl enclosing rock fragments. Somewhat similar features are to be seen in the eastern face of the lower gallery where a characteristic pipe, 20 feet across, 16 to 18 feet deep, and with steep sides, is partnered by a marl-filled structure of similar width but only 8 feet deep and whose floor is pitted with holes 1 to 2 feet deep and 2 to 4 feet across. Beyond the latter the marl band thins rapidly and bifurcates into two seams of grey-green marl as compared with the dominant brick red-brown in the near-by pipes. These two seams are separated by 18 inches to 2 feet of pseudobreccia. No haematite was seen beneath this lower marl, but there appears to be no reason why this should not occur in the same manner as with the top band.

Below the lower marl band there is a repetition of similar massive limestones as previously described, but pseudobreccias and some beds assuming the nature of true breccias are now characteristic. These brecciated beds are best seen in the low bank in the south-central portion of the main gallery. The irregular base of the lower marl here is floored by a bed, 2 to 3 feet thick and increasing in the vicinity of joints, in which individual fragments can be easily picked out from

the grey-green marly matrix. These fragments are generally irregular and sub-angular with average dimensions of 1 to 2 inches. Small boulders or large fragments up to a foot or more in length, however, are not infrequent. The larger fragments in themselves are often pseudobrecciated. Below this breccia bed is a massive rock, 3 to 4 feet thick, clearly displaying a brecciated structure but very hard and compact. Thin films of marl are to be observed in some of the interstices, but subsequent dolomitization of the matrix appears to have played no small part in the compaction of this rock.



TEXT-FIG. 5.—Comparative graphs showing variation in the depth of the sea in which the upper zones of the Carboniferous Limestone of Gower and the South Cornelly area were deposited.

Where the lower marl thins to about 1 foot in thickness, as in the western end of the southern face, the underlying rock generally shows a brecciated or pseudobrecciated structure. The latter predominates and the beds are massive and compact. Occupying a major bedding plane an impersistent seam of grey-green marl, 6 inches to 1 foot thick and enclosing fragments of rock, is traceable 10 feet below the lower marl. Traces of a further thin seam are sometimes evident some 3 to 4 feet below the latter and associated with an ill-defined bedding plane.

CONCLUSIONS

The evidence afforded by these new sections suggests that the conditions of deposition for the top half of the sub-zone of D_1 (Lower Dibunophyllum Sub-zone) and possibly the overlying portion of D_2 (Middle Dibunophyllum Sub-zone) underwent rapid fluctuations. The crystalline limestones with their brachiopod and coral fauna must be attributed to original fairly deep and clear water conditions. These were followed by uplift to unstable inshore conditions when there was probably some degree of brecciation of the top of the consolidated limestone. A period of emergence followed during which the limestone was pitted and piped by subaerial agencies. The marls that fill these irregularities are completely devoid of organic remains, and it is postulated that they were laid down in shallow lagoons of high salinity and isolated by temporary barriers from open water.

This cycle of events was repeated, and from the degree of piping it appears that the second emergence was of greater amplitude or of greater duration than the first. Limited exposures at these horizons make it impossible to determine how localized this piping is. However, the conditions of deposition interpreted by Dixon and Vaughan (1911) for the lower middle portion of the Dibunophyllum Zone of Gower, where the presence of thin carbonaceous bands was thought to have been due to sharp diminutions in the depth of the sea floor, appear to have been carried a stage further with two periods of actual emergence in this portion, at least, of the west Vale of Glamorgan.

Minor clots and irregular streaks of red marl within the comparatively pure massive limestones and well removed from brecciation effects or major jointing are difficult of explanation. The possibility of a windblown origin for these might be suggested. It was noted by Robertson and George (1929) that the purple and green marls or clays topping the Caninia Oolite on part of the north crop in south-east Brecknockshire might be related through such agency to the contemporary volcanic activity of the north Somerset area. No volcanic activity has been recorded at the Dibunophyllum horizon in the South-West Province.

The writer wishes to thank Dr. F. J. North, Keeper of the Geological Department, National Museum of Wales, for reading the manuscript and making valuable suggestions thereon. He also wishes to record the ready facilities given by Messrs. C. and F. Gaen, quarry owners, for field inspection of these sections and their permission for publication of the findings.

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Bryn Bach,
Bettws,
Near Bridgend,
Glam.

Zonal Variations in Selected Morphological Features of *Echinocorys scutata* Leske

By N. R. Willcox

Abstract

Selected morphological features in the test of zonal assemblages of *Echinocorys scutata* Leske from the Upper Chalk of Berkshire, Buckinghamshire, Hampshire, and Wiltshire, have been examined and measured. The results suggest that the changes observed in these characters at certain levels in the Chalk would have made *Echinocorys* more suited to a burrowing or partially burrowing habit. These adaptations are associated with lithological indications of shallow water deposition. It is suggested that the shallowing of the sea was the environmental stimulus behind the adaptations towards a burrowing mode of life.

Introduction

Echinocorys scutata is the only echinoid which is represented in all the zones of the Upper Chalk of Southern England in sufficient numbers to make it a potentially valuable zonal guide. The shape and size of the test have been used successfully by many workers, notably Brydone (1912), as zonal and sub-zonal indices. It is intended to show in the present paper that other morphological features, considered in conjunction with the shape and size of the test, throw light on the mode of life of *Echinocorys* and on the bathymetric conditions of the Upper Chalk sea in which it lived.

Examination of the selected morphological features has been carried out in the following manner :—

1. Measurements have been made on the apical systems of specimens from different zonal assemblages to express the changes from zone to zone in the size and shape of the system. These changes are shown in Text-figs. 2 and 5.

2. The supra-ambital ambulacral pores have been measured so that changes in the shape of the pores in the various zonal assemblages and the position of the largest pores within the supra-ambital ambulacra may be expressed graphically (Text-figs. 3 and 4, and Text-fig. 6).

3. Development of peripodia above the ambitus has been observed in the variety *cincta*.

The specimens used have either been collected by the author or are in collections made by Professor H. L. Hawkins (preserved in the Geological Museum, Reading University), R. M. Brydone (in the Sedgwick Museum, Cambridge, and the Geological Survey Museum), Ll. Treacher (in the Geological Museum, Reading University), R. Blackmore (in the British Museum (Nat. Hist.)), and E. Williams-Mitchell, Esq. (in the Geological Survey Museum). As many as possible of the localities from which these collections were made have been visited

and all the zonal groups include specimens which the author has collected himself. Some of these groups are small in number, but it seemed preferable to use small numbers whose locality and horizon were dependable, rather than swell the numbers with specimens of uncertain provenance.

The author acknowledges his indebtedness to Professor H. L. Hawkins, F.R.S., who has given encouragement and advice in the preparation of this paper ; to Professor P. Allen, and Mr. R. V. Melville for reading and criticizing the manuscript ; to Mr. L. Bairstow and Mr. A. G. Brighton who have rendered valued assistance ; and to the Department of Scientific and Industrial Research for a research grant whilst carrying out this work.

TABLE 1.—THE STRATIGRAPHICAL UNITS USED IN THE TEXT

Zone of *Actinocamax quadratus*
Belt of *E.s.* var *cincta*
Sub-zone of abundant *O. pilula*
Belt of *E.s.* var *truncata*
Zone of *Offaster pilula*
Belt of *E.s.* var *depressula*
Sub-zone of *E. scutata* var *depressula*
Belt of *E.s.* var *tectiformis*
Zone of *Marsupites testudinarius*
Zone of *Uintacrinus*
Zone of *Micraster coranguinum*
Zone of *Micraster cortestudinarium*
Zone of *Holaster planus*

STRATIGRAPHICAL UNITS EMPLOYED

The system of zonation presented in Table 1 is approximately that evolved by Brydone (1912).

The author is aware of the fallacy of giving equal value to zonal and sub-zonal and even finer divisions in the graphs in which they appear ; for example, of making 10 feet of the chalk of the *pilula* zone (the var. *truncata* belt) the equivalent of 250 feet of chalk constituting the *M. coranguinum* zone. It is not possible to correlate the time taken to deposit any given thickness of chalk from different zones. It will be pointed out later in this paper that there is lithological evidence (in the presence of phosphatic chalks and rock bands) of slow deposition in two zones of the Upper Chalk in the area studied. The time taken to deposit a given thickness of chalk in one of these zones may bear little relationship to that taken to deposit a similar thickness from the same zone but in a different locality ; it may bear still less relationship to an equal thickness from some other zone.

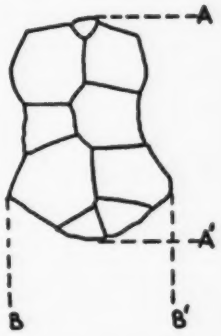
The impossibility of assessing the speed at which evolutionary and adaptational changes occurred results from the absence of an absolute chronological scale. Misleading as the independent axes

in the graphs are, the author considers that an attempt to arrive at an absolute chronological scale would prove even more misleading.

Morphological Variation

1. *Apical System.*

A. The area of a rectangle enclosing the apical disc has been found by measuring the distance between the anterior edge of ocular plate III and the posterior margin of oculars I and V (A–A′), and multiplying this quantity by the width of the system across the 1st and 4th genital plates (B–B′). It was found that variation in the area of the apical system from one zonal group to another was to some extent independent of variation in the mean length of the test. Since both these dimensions increase as a result of growth with age, it was necessary to eliminate this factor before directly comparing, as between different zonal assemblages, the ratio of length of test to area of apical system. This has been done by dividing the latter by the square of the former. An absolute size of the apical system is thus found, independent of the age of the specimen.

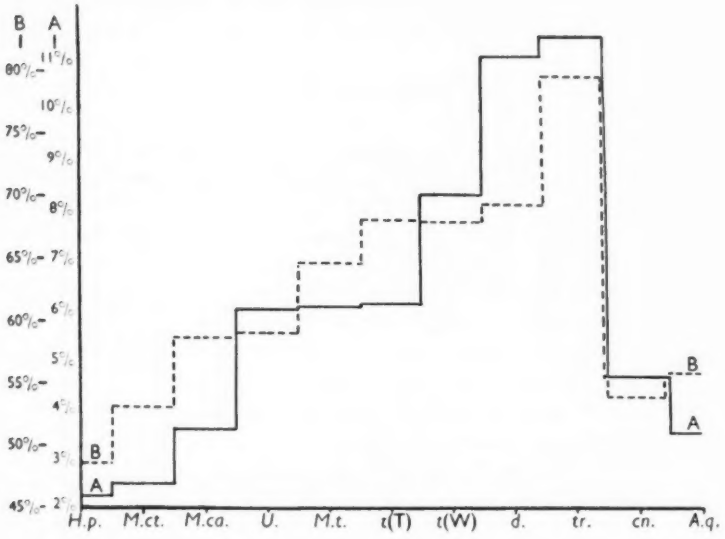


Text-fig. 1.—Diagram to illustrate measurements of the apical system.

The results are expressed in Graph 2A, based upon the data given in Table 2. It is seen that the quantity "area of the apical system divided by the length of the test squared" increases progressively to a peak in the zone of *Offaster pilula* and then declines. This increase could be a result of an increase in the area of the apical system, or the system might have remained constant in size whilst the test length declined. However, it can be seen from Table 2 that the mean length and breadth of the apical system in the variety *truncata* (that with the lowest mean length of the test) are still comparable with those in the group from the zone of *M. coranguinum.*

B. Increase in the area of the apical system is not achieved by similar proportional increments to the length and to the breadth of the system. Thus ratios of these two measurements show that the width, relative to the length of the apical system, increases more rapidly, and that the disc tends to change from an elongated to a more rounded shape. These ratios are plotted in Text-fig. 2B, the relevant information being found in Table 2. Again the graph shows a peak in the zone of *O. pilula*, thereafter falling off.

Semi-diagrammatic drawings of the apical systems of representative individuals from several zonal and sub-zonal communities (Text-



TEXT-FIG. 2

A. Zonal and sub-zonal variations in the ratio of the area of the apical system to the square of the length of the test, expressed as a percentage.

B. Zonal and sub-zonal variations in the ratio width : length of the apical system, expressed as a percentage. *H.p.*, *Holaster planus* zone. *M.ct.*, *Micraster cortestudinarium* zone. *M.ca.*, *Micraster coranguinum* zone. *U.*, *Uintacrinus* zone. *M.t.*, *Marsupites* zone. *t*(T)., var. *tectiformis* (Taplow). *t*(W)., var. *tectiformis* (Winterbourne). *d.*, var. *depressula*. *tr.*, var. *truncata*. *cn.*, var. *cincta*. *A.q.*, *A. quadratus* zone.

TABLE 2

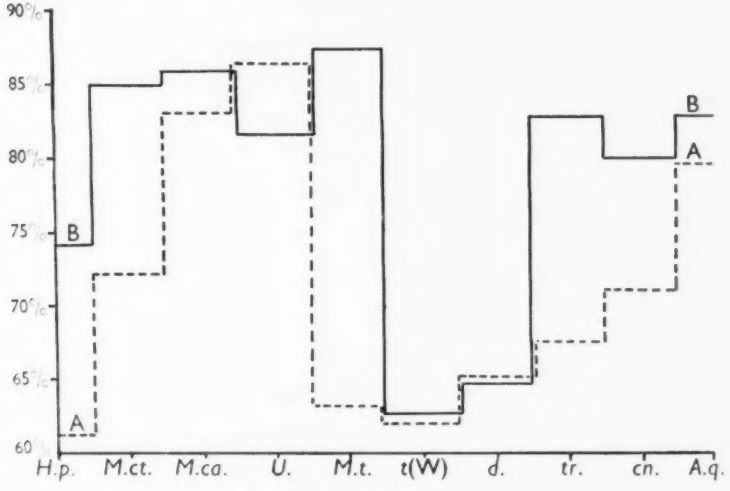
1	2	3	4	5	6	7	8	9
Community.	*Number of Specimens.*	*Mean Test Length.*	*Mean Length Ap. Syst.*	*Mean Width Ap. Syst.*	*Ratio* 5 : 4	*Ratio* (4 × 5) : 3 ²	*Stan. Dev.* 7.	*Stan. Error* 7.
					%	%		
A. quadratus .	96	54·0	12·9	7·49	55·8	3·46	0·88	0·0084
var. *cincta* .	21	49·2	14·7	7·60	53·7	4·52	0·79	0·18
var. *truncata* .	19	36·5	13·6	10·8	79·5	11·32	1·85	0·43
var. *depressula*	4	51·5	20·6	14·3	69·1	11·0	2·31	1·37
var. *tectiformis* (Winterbourne).	16	50·1	16·2	10·8	67·7	8·2	2·04	0·53
var. *tectiformis* (Taplow).	24	51·8	15·4	10·5	68·0	6·06	1·49	0·305
Marsupites .	22	61·3	18·5	11·9	64·5	5·92	1·58	0·33
Uintacrinus .	19	63·5	20·0	11·7	58·7	5·89	1·36	0·31
coranguinum .	19	59·1	14·5	8·7	58·5	3·54	0·84	0·19
cortestudinarium.	10	57·6	11·8	6·3	53·0	2·45	0·51	0·17
H. planus .	31	54·2	11·6	5·6	48·5	2·24	0·63	0·11

All measurements in millimetres.

fig. 5) illustrate the change in shape which results from the differential increase in size of the 1st and 4th genitals.

2. *Ambulacral Pores.*

A. The shape of the pores on the upper surface of the test varies from elliptical to more nearly circular. The two pores in a pair are independent of one another both in size and in shape. The variations in shape are reflected by the graphs in Text-fig. 3, the length and breadth of the upper fifteen pore pairs having been measured. The ratio of breadth to length for each member of the pore pair has been calculated separately. It is found that the most elliptical pores are met with



TEXT-FIG. 3

A. Zonal and sub-zonal variations in the shape of the outer pores of the upper part of the supra-ambital half ambulacrum. Shape expressed as the ratio short axis : long axis of pores expressed as a percentage.

B. The same for the inner pores of the half-ambulacrum.

in groups from the zones of *O. pilula* and *H. planus*. Pores from the upper part of ambulacrum I or V of two or more representatives of each stratigraphical subdivision were measured and several of these are drawn (Text-fig. 6) to illustrate the changes in shape. Measurements were made on individuals selected at random and further measurements were made on other random specimens as a check. As an additional check the pores of many other specimens of *Echinocorys* have been examined under the microscope and the shape of their pores noted.

B. It was observed that the largest pores are not uniformly distributed in the supra-ambital part of each ambulacrum. The location of the larger pores has therefore been determined as follows. First, in ambulacra I or V, the outer series of pores in one column (i.e. in columns I*a*, I*b*, V*a*, or V*b*) was selected for examination. The selection was dictated by extraneous factors such as preservation, freedom from encrustation, etc. The number of ambulacral plates between the ocular plate and the ambitus was counted and divided by two to give the

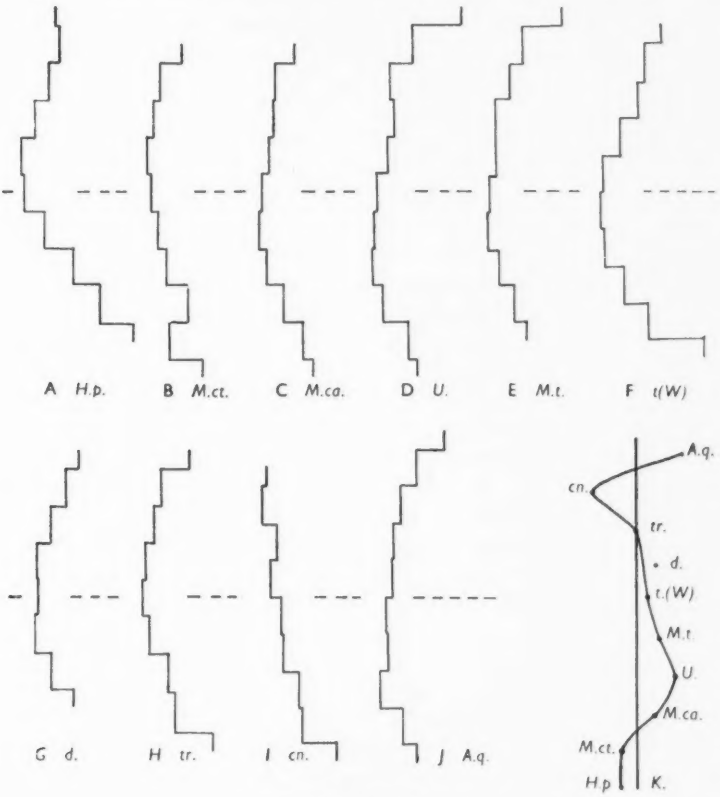
TABLE 3.—MEASUREMENTS CARRIED OUT ON VAR. *depressula* SPECIMENS

1				2	3	4	5
Pore-size (units arbitrary). Specimens.				*" Composite Ambulacrum."*	*Mean pore-size.*	*Ratio mean pore-size : pore-size × 10.*	*Grouped in threes.*
1	2	3	4				
—	—	—	—	—	Sum. col. 2	—	
5	—	—	—	5·0	divided by	13·4	
6	—	6	5	5·7	no. of	11·8	12·1
6	—	5·5	7	6·1	" pores ".	11·0	
6	—	5·5	6	5·8	$\frac{181\cdot8}{27} = 6\cdot7$	11·6	
6	7	6·2	6	6·3		10·9	10·8
6	7	6·7	7	6·7		10·0	
—	8	7	7	7·3		9·2	
8	7	7	6	7·0		9·5	9·4
6	8	7	7	7·0		9·5	
—	—	7·5	—	7·5		8·9	
—	9	8	7	8·0		8·1	8·5
—	10	8	7	8·3		8·1	
—	10	8	7	8·3		8·1	
—	11	7	7	8·3		8·1	8·5
—	7	7	8	7·3		9·2	
8	10	8	9	8·7		7·7	
—	10	8	6	8·0		8·4	7·9
8	10	8	9	8·7		7·7	
8	8	7	7	7·5		8·9	
7	9	6	8	7·5		8·9	9·3
7	7	5	8	6·7		10·0	
—	—	5	7	6·0		11·2	
5	6	5	6	7·1		9·4	11·1
6	—	5	5	5·3		12·7	
5	—	4·5	3	4·2		16·0	
—	5	4	—	4·5		14·9	17·8
—	—	—	3	3·0		22·5	
—	—	—	—	—		—	

mid-point of the supra-ambital ambulacrum. The short (meridional) axis of the pores was then measured under the microscope with a micrometer eyepiece. The largest pores so discerned could be localized in relation to (1) the ocular plate, (2) the ambitus, and (3) the mid-point (in terms of the number of plates) of the supra-ambital part of each ambulacrum.

In order to compare the different distributions of pore-size in the various zonal assemblages, a composite value for each assemblage

was necessary. This was arrived at in the following way. It was assumed that pores equidistant (in terms of number of plates) above the mid-point of the ambulacra in different specimens were homologous (and similarly for those below the mid-point). The lengths of the



TEXT-FIG. 4

A–J. Size-distribution of pores around the centre of the " composite ambulacra ", represented by the broken line. Each vertical step represents the average of a group of three " composite pores." Each horizontal step to the left represents an increase in pore-size (and vice versa). Abbreviations as for Text-fig. 2.

K. Graph giving deviation of the largest sized pores from the centre of the " composite ambulacrum " in the different communities.

short axes of a group of homologous pores could thus be averaged for each zonal assemblage to give a " composite pore " ; and the vertical series of " composite pores " gave a " composite ambulacrum ". The " composite pores " are expressed as a ratio of the mean of " pore " size, multiplied by 10 (see col. 4, Table 3).

In order to simplify the presentation of the data, the " composite pores " have been grouped in threes and averaged. Thus each " composite ambulacrum " as here graphed (Text-fig. 4) is built of the averages of three groups of homologous pores, expressed as a ratio of the mean pore size for the " composite ambulacrum ".

The relation of the peak of pore-size to the centre of the " composite ambulacrum " from zone to zone is summarized in the final graph (Text-fig. 4K) which illustrates the deviations of the maxima of pore size.

C. Peripodia normally occur only on the adoral surface of the test in *Echinocorys* but in specimens from the belt of the variety *cincta* these continue until some three or four plates above the ambitus.

Significance of the Variations

In the preceding section four characters have been described and the results are thought to establish the following changes in *Echinocorys*.

1. Increase in the size of the apical system (that is the absolute size of the system, having eliminated changes due to the growth of the test, see p. 85), up to the middle of the *pilula* zone and decrease above that horizon.

2. A tendency for the apical system to become rounder at successive stratigraphical levels, the greatest expression of the trend again being reached in the *pilula* zone.

3. The change in the outer row of ambulacral pores is from a slit-like shape in the *planus* zone to a more circular shape in the *coranguinum* and *Uintacrinus* zone and back to the elliptical again in the two succeeding zones. As in the characters outlined above, specimens from the *quadratus* zone show reversion to a morphological condition comparable to that which obtained before the chalk of the *Marsupites* zone was laid down. The inner row of pores of a half ambulacrum is less apt to develop the slit-shape but again this tendency is most marked in the *pilula* zone.

4. The largest pores do not remain in the same position relative to the centre of the ambulacra in the various communities of *Echinocorys*. Peripodia, in the variety *cincta*, are continued on to the upper surface of the test.

These four changes may be considered in conjunction with others long known and used by workers in the Chalk (see, for example, Brydone (1912)). The size of the test tends to increase, in specimens from Southern England, from the *planus* to the *coranguinum* zone and then declines slightly in the *Uintacrinus* and *Marsupites* zones (Hayward, 1940). Chalk of the lower part of the *depressula* sub-zone, though normally barren of the zonal fossil, is characterized by the transition in size to the smaller *E. scutata* var. *tectiformis*. The size

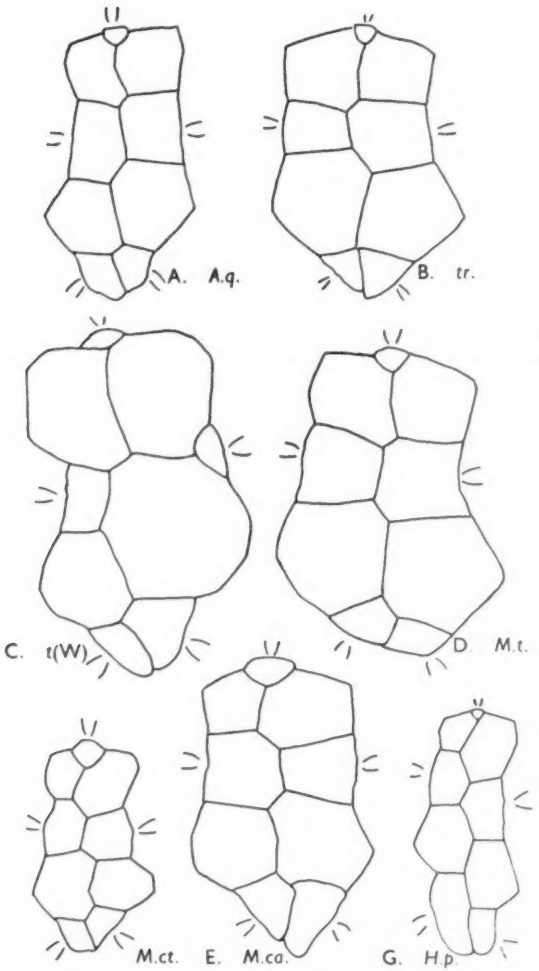
of the test falls to a minimum in the var. *truncata*, which is characteristic of the base of the *pilula* sub-zone, and then increases in the *quadratus* zone.

The shape of the test broadly follows a similar pattern of variation. The specimens from the *planus* and *cortestudinarium* zones have the summit of the test rounded, with inflated flanks, an indistinct rounded ambitus and a tumid plastron which, with the rounded ambitus, makes the adoral surface convex. In higher zones (*coranguinum* to *Marsupites*) the test becomes increasingly elevated and has declivitous flanks making an abrupt junction with the flat adoral surface. The test again becomes depressed in the *pilula* zone, and the flanks, in the varieties *depressula* and *cincta* are rounded. The adoral surface remains flat but the rounded ambitus shows resemblance to the form from the *planus* zone. As in all the other characters studied, there is reversion in the *quadratus* zone, a more elevated form becoming established.

The changes discussed above may be interpreted as adaptations to a burrowing mode of life. They closely follow lithological changes in the Chalk of that part of Southern England which has been sampled and their common reversion to approximately a previous level of development in the *quadratus* zone is accompanied by a repetition of earlier facies by the chalk of this zone at the western end of the London Basin.

A small and depressed form of the test is taken by Kongiel (1949, p. 34), to be one indication of *Echinocorys* having assumed or having attempted to assume a burrowing habit, for it is supposed that such an echinoid test could have become buried in the ooze more easily than a large and elevated test.

Drawings of the apical systems of representatives of some of the zonal and sub-zonal communities sampled, show that the increase in area of the apical system results from enlargement of the genital plates : the ocular plates become relatively smaller. Text-fig. 5C shows the partial result of a process which if it had been carried to its conclusion, or had had time to attain this conclusion before the environmental stimulus receded, would have resulted in a spatangid type of apical system. Kongiel (1949, p. 22) points out that by arranging the ocular plates in an outer ring, *Echinocorys* would have been able to develop petals and change to an ethmolysian condition. Extension of the madreporic genital would obviously have become possible under these circumstances. The connection with the development of petals is not clearly understood, though it seems a general rule in echinoids that petals are always associated with exsert ocular plates. In the *Echinocorys* studied, Kongiel's contention is supported by the evidence of a tendency to modify the apical system towards the exsert condition, which is the only one found in association with petaloid ambulacra.



TEXT-FIG. 5.—Semi-diagrammatic outlines of representative apical systems to illustrate changes in size and shape. Length of test in A, 51 mm.; B, 38 mm.; C, 48 mm.; D, 56 mm.; E, 52 mm.; F, 56 mm.; G, 51 mm. All drawings × 3. Abbreviations as for Text-fig. 2.

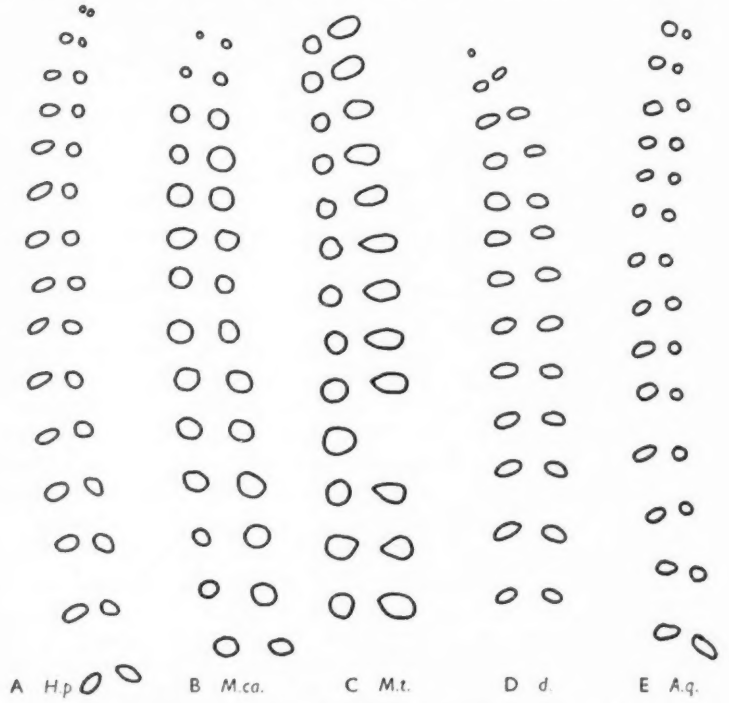
This development is commonly associated with a burrowing habit, so that a tendency towards the formation of petals in *Echinocorys* may legitimately be interpreted as an adaptation towards this mode of life. It should be emphasized that, though changes in the relative position of the largest pores may indicate the first stages in the formation of petals, true petals do not occur in *Echinocorys*.

These changes, shown in Text-fig. 4, may indicate varying depth conditions. In the group from the *planus* zone the largest pores are found above the mid-point of the supra-ambital part of the "composite ambulacrum" and there is an abrupt fall-off in size below this point. If pore-size may be interpreted as an estimate of the respiratory efficiency of the tube-feet, this localization of the functionally more efficient pores in the upper half of the supra-ambital ambulacrum is an approach to the petaloid condition. It is found in lithological association with the shallow-water conditions (Jukes-Browne, 1904, p. 361) of the Chalk Rock.

The respiratory efficiency of the ambulacra may be increased either (1) by their becoming more petaloid or (2) by the extension of the functional pores further up and down the upper surface of the test. In the *cortestudinarium*, *coranguinum*, *Uintacrinus*, and *Marsupites* zonal assemblages, the size range of the pores decreases and in the last three zonal groups there is shift of the largest pores towards the ambitus. The second method of evolution of the ambulacra is that followed by *Echinocorys*. This process might have continued if the depth increased or remained constant and the environment tranquil, until the larger pores were so near the ambitus as to be in danger of becoming fouled by the ooze *over* which the urchin moved. It is likely to have been arrested or reversed if bottom conditions altered in such a way as to encourage or compel *Echinocorys* to assume a partially burrowing mode of life. Such a reversal does indeed take place, reaching a maximum in the group from the *cincta* belt. The transition first becomes apparent in the variety *tectiformis*, where the pores from near the ambitus resemble those of the community from the *planus* zone in their small size and presumed loss of respiratory function. As in the group from the *planus* zone the localization of the larger pores towards the apical system and the very small size of those approaching the ambitus are associated, in the west of the London Basin, with evidence of retarded or arrested deposition, such as rockbands and phosphatic chalks, which may be held to indicate shallowing. The graph, Text-fig. 4K, if placed with the line through the mid-points of the ambulacra horizontal, serves as a rough bathymetric chart of the sea in Southern England from the *planus* zone to the *quadratus* zone.

The changes in shape of the tube-feet again accompany lithological indications of changes in the depth of the sea. In general the respiratory efficiency of a tube-foot will be increased by change in shape of the organ from that of a tube to a ribbon which presents a greater surface area to the respiratory medium (the sea water). Change in shape of the outer row of pores from elliptical (in the assemblage from the *planus* zone) to nearly circular (in that from the *coranguinum* zone) reflects

such alterations in shape of the tube-feet. Adaptative alteration of the tube-feet in the group from the *pilula* zone caused the pores to become slit-like once more and then in the *quadratus* zone they reverted to a more nearly circular shape. Increased respiratory efficiency of the tube-feet coincides zonally with the petaloid tendencies noted in the previous paragraph. The concentration of tube-feet (made more



TEXT-FIG. 6.—Camera lucida drawings of representative ambulacra to illustrate changes in shape and size of the pores. All drawings to the same scale. Abbreviations as for Text-fig. 2.

effective as organs of respiration by increase in size and surface area) in the upper half of the supra-ambital ambulacrum is a clear tendency towards true petals. The two zones in which the combination occurs have equally clear indications of shallow water deposition. Lambert (1903, p. 21) observed that in the "*Ananchitidae*" (to which family *Echinocorys* belongs), the number and development of the ambulacral tentacles tended to increase with the shallowing of the sea.

One further and most significant pointer to a burrowing mode of existence is the continuation in var. *cincta* of pores in peripodia up to three or four plates above the ambitus. In most other groups

this condition is restricted to the adoral surface, upon which the peripodia may be interpreted as affording protection from the continual abrasion of the ambulacral tentacles during the passage of the urchin over the ooze. That such a protective adaptation should have developed on the supra-ambital surface in the variety *cincta* is suggestive of its partial immersion of the test in the ooze.

Conclusions

Kongiel (1949, p. 34) lists the following characters to be expected in an *Echinocorys* which has taken to a burrowing mode of life : smaller, shorter, and flatter test ; more rounded apical system ; peristome nearer the anterior margin of the test ; periproct more elevated. Further, the tubercles at the margin of the test become eccentric within the scrobicules and those on the under, adoral, surface less strongly developed : it is interesting to note that the most strongly tuberculate tests come from the *coranguinum* zone. He also would have expected, but did not find, an increased concentration of ambulacral pores around the apex. In the *pilula* zone of those parts of Buckinghamshire, Berkshire, Hampshire, and Wiltshire, from which examples have been examined, most of his requirements are met except for the eccentricity of the tubercles within the scrobicules. The elevation of the periproct and the eccentricity of the peristome are difficult to express quantitatively and are not here considered.

Several of the characters of *Echinocorys* in the *pilula* zone, such as the size and shape of the test and the condition of the ambulacra, which indicate partial burrowing, were previously developed in the *planus* zone. This repetition in association with the Chalk Rock on the one hand, and with numerous rock bands and several phosphatic chalks in Berkshire and Buckinghamshire on the other, suggests shallowing water as the stimulus behind the morphological changes.

It is significant that the Hampshire and Wiltshire Chalk of this (*pilula*) zone should, though apparently without rocks of phosphatic chalks, contribute *Echinocorys* as indicative of shallow water as those from the rocky chalk of Kintbury and the phosphatic chalk of Taplow. The marl seams and scarcity of flints in this zone in the Chalk of Hampshire may be properties of a shallow water facies. From the evidence of the *Echinocorys* it would seem that the Senonian sea, whose greater depth in *coranguinum* zone time in Southern England has been appreciated for some time (Neaverson, 1928, p. 420), shallowed sharply in the *pilula* zone and then deepened again whilst depositing the chalk of the *quadratus* zone. The shallow water facies of the phosphatic chalks of *pilula* age in Buckinghamshire and Berkshire has already been recognized (Strahan, 1896 ; Cayeux, 1939, p. 253). These are not isolated pockets but the extremes in a shelved sea which was shallow

over the whole area of the four counties from which examples of *Echinocorys* have been examined.

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DEPARTMENT OF GEOLOGY,
THE UNIVERSITY,
READING.

A New Species of *Lepidostrobus* containing unusual Spores

By W. G. Chaloner

(PLATE II)

Abstract

A new species of *Lepidostrobus*, *L. zea*, is described. Two cones, from Yorkshire and from Ayrshire, and some isolated megasporangia are known. The megaspores have long been known, occurring isolated in coal, and have been described as *Triletes auritus* Zerndt. The microspores, also known previously from coal macerations, are of the type described as *Endosporites globiformis* (Ibrahim) (*E. zonalis* (Loose) and the C1 type of Raistrick). *Endosporites* has hitherto been regarded as cordaitalean (gymnosperm) pollen, and this is the first record of *Endosporites* from a lycopod.

Lepidostrobus zea sp. n.

(Pl. II, fig. 1, Text-fig. 1).

" *Sigillariostrobus* " Kidston, 1897 (pl. ii, fig. 1a and b).

" Sporangium " Kidston, 1897 (pl. ii, fig. 12a and b).

Diagnosis.

Cone cylindrical, up to 5 cm. diameter and over 7 cm. in length. Axis forming approximately half the diameter of the cone. Sporophylls composed of a short horizontal part, attached to the axis, passing distally into a relatively long narrow ascending sporophyll lamina, up to 3 cm. in length and 8 mm. in width. Sporangia mounted on the upper surface of the horizontal part of the sporophyll, relatively short, up to 1·3 cm. in length (perpendicular to the cone axis) and 7 mm. in height (parallel to the cone axis).

Megaspores, borne in the lower sporangia of the cone, agreeing with *Triletes auritus* Zerndt, 1930. Greatest diameter of the flattened spore (including the three ear-like expansions) 520–1024μ, mean value 800μ (for ninety-eight spores measured). Tri-radiate ridges up to 50μ high, reaching to about two-thirds of the spore radius, with a small expansion usually formed at their point of confluence. Three more or less semi-circular flaps developed at the spore equator, opposite the tri-radiate ridges. Megasporangia containing several hundred spores.

Microspores borne in the upper sporangia of the cone, agreeing with *Endosporites globiformis* (Ibrahim) Schopf, Wilson, and Bentall (*E. zonalis* (Loose, 1934), and the C1–C4 group of Crookall and Morris, 1952, in part). Microspores formed of a central spheroidal body, enclosed in an inflated air-sac which, in the flattened spore, usually appears to have a thickened rim. Air-sac, in the unflattened spore, discoidal in shape ; fused with the central spore-body on the proximal face, but only appressed or passing close to it, on the distal face. Greatest diameter of the flattened central body 26–51μ, mean value

40μ (for 300 measured) : of the surrounding air-sac, 80–128μ, mean value 102μ (for 100 measured). Tri-radiate ridges extending to the margin of the central spore body, with folds sometimes extending from them on to the surrounding air-sac, beyond the central body margin. Small dark inter-radial papillae usually visible close to the centre of the proximal face of the spore, between the tri-radiate ridges. Wall of air-sac micro-punctate to micro-reticulate.

Holotype (Pl. II, fig. 1, Text-fig. 1), nos. 4838 and 4839 (part and counterpart).—Kidston Collection, Geological Survey and Museum, London. From the Barnsley Bed, Monckton Main Colliery, near Barnsley, Yorkshire.

Time Range.—This species is recorded only from the lower *similis-pulchra* zone, Coal Measures of Yorkshire and Ayrshire.

Material.—The description of this species is based on three specimens in addition to the holotype, all in the Kidston Collection, Geological Survey and Museum, London. Their registered numbers are given below :—

1573 : A rather poorly preserved cone from the horizon of the Major Coal, Springhill No. 3 Pit, Crosshouse, Ayrshire. (This horizon is included in the lower *similis-pulchra* zone by Weir and Leitch, 1936.) This cone was figured by Kidston (1897, pl. ii, fig. 1) as "*Sigillariostrobus*".

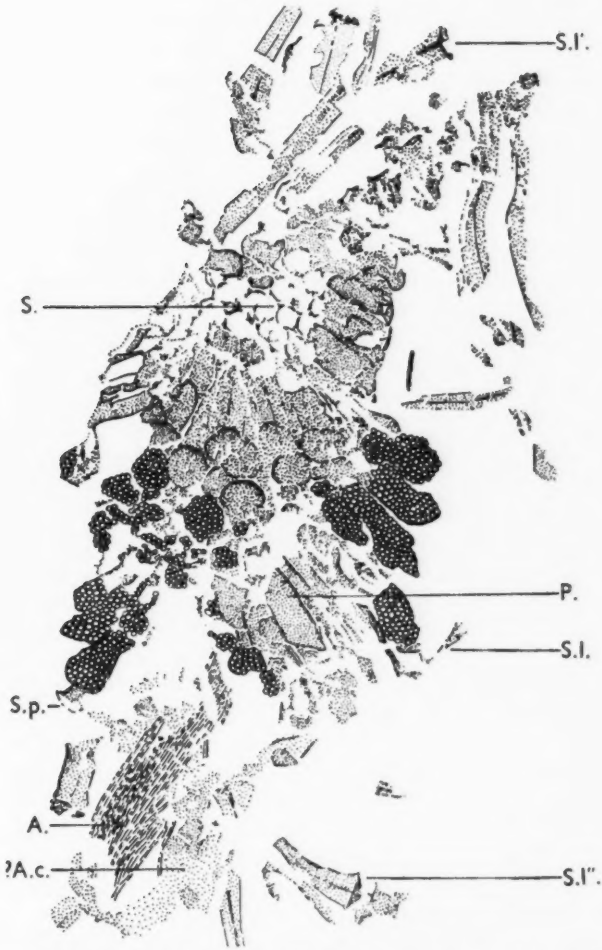
1669 : A single isolated megasporangium from the horizon of the Barnsley Bed, Wooley Colliery, Darton, Yorkshire. Figured by Kidston (1897, pl. ii, fig. 12) as a "sporangium".

1273 : A group of megasporangia from the same locality, mentioned by Kidston (1897).

I have chosen the specific name "*zea*" because of the resemblance of the cone to a large maize cob.

The Structure of the Cone.

Owing to the nature of the preservation of the material, only the general structural features of the cone can be made out. The holotype is only a short piece of what was once presumably a much longer cone, which had apparently been broken at either end before fossilization. No remains of tissue representing the axis can be seen ; the fragment of striated carbonaceous material lying obliquely in the left corner of Plate II, fig. 1 and Text-fig. 1 (marked A), which at first sight suggests an axis, I believe to be extraneous in origin. It lacks any sign of attachment of the sporophylls, even within the area of the cone, and appears to pass out of the surface of the specimen in the lower part of the cone, as it is followed along its length. The axis is represented rather by a space, filled with matrix, at the core of the cone ; the outlines of the adaxial ends of the sporangia, which would have



TEXT-FIG. 1.—The holotype of *Lepidostrobus zea* sp. n., × 1. The parts shaded black with white circles represent areas where megaspores are, or have been, present. S: impression of the adaxial ends of sporangia on the cast of the axis. Sp.: the horizontal part of the sporophyll projecting from beneath a megasporangium. A: extraneous organic matter, simulating an axis. ? A.C.: ? bark of *Asolanus camptotaenia*. Sl., Sl.', Sl.": sporophyll laminae. P: the horizontal part of a megasporophyll, with its corresponding megasporangium missing. (No. 4838, Kidston Collection, Geological Survey and Museum, London.)

been left abutting on this space as the axis decomposed or fell out, can be seen forming a lattice-like pattern in the upper central part of Plate II, fig. 1, and Text-fig. 1 (marked S).

The holotype is about 5 cm. in diameter and the sporangia are about 13 mm. long ; if twice the length of the sporangia is subtracted from the cone diameter, this would leave about 24 mm. for the cone axis. The appearance of the matrix-filled space in the upper part of the cone representing the cast of the axis, agrees with this interpretation of the width of the axis.

Megaspores are present in all the sporangia visible in the lower part of the holotype, and microspores have been obtained from the upper part of the cone. A similar demarcation between the megaspore- and microspore-bearing sporophylls can be seen in the Ayrshire cone (cf. Kidston, 1897, pl. ii, fig. 1). Sporangia in which the flattened megaspores are present, or in which their presence is indicated by circular depressions in the matrix, are shown by white circles on black in Text-fig. 1. In the lower central part of the cone some of the megasporangia are missing, and the horizontal part of the sporophylls are exposed (marked P in Text-fig. 1).

Only one sporophyll lamina is actually visible in organic connection with the cone, and this is seen in section at the right-hand side of the holotype, turning sharply at right-angles to the sporophyll pedicel on which it is borne (S1 in Text-fig. 1 : the sporophyll concerned is a little displaced in the cone). A number of isolated, single-veined leaf-like bodies of uniform width, or tapering slightly, are present on the same slab of shale as the holotype, and are intimately associated with the cone. Several of these (Sl.′, Sl.″, Text-fig. 1) show at one end what is probably the line of junction with the horizontal part of the sporophyll. One megasporangium also shows the horizontal part of the sporophyll projecting from beneath it (S.p., Text-fig. 1), although the sporophyll lamina is missing here.

The sporophylls in the holotype are strongly drooping, especially in the lower part of the cone. Although this specimen does not clearly show the mode of arrangement of the sporophylls on the axis, the Ayrshire specimen (cf. Kidston, 1897, pl. ii, fig. 1) suggests an arrangement of alternating whorls.

The Generic Attribution of Lepidostrobus zea sp. n.

I believe *Lepidostrobus zea* to be correctly placed in the Lepidodendraceae because of its general cone structure, with the sporangia placed on the upper surface of the sporophylls, coupled with its advanced degree of heterospory.

Lepidostrobus is the chief genus of Carboniferous lycopod cones, many of which were no doubt borne on trees of the type called *Lepidodendron*. For the majority of these cones, proof of connection with the parent tree type is lacking : some may, for example, have been borne on *Sigillaria*. Kidston (1897) assigned *Lepidostrobus zea* to

Sigillariostrobus—a genus normally reserved for cones believed to have been borne on *Sigillaria*—and claimed it as evidence that some sigillarian cones were bisexual. Unfortunately, he gave no substantiation for attributing the cone to *Sigillariostrobus*, and Schopf (1941, p. 30), has justifiably queried this conclusion. In fact, no bisexual cones reliably attributed to *Sigillaria* are known (Schopf, loc. cit.). There seems no evidence for placing *Lepidostrobus zea* in *Sigillariostrobus* : and in view of its general similarity to other cones assigned to *Lepidostrobus*, I believe it is rightly placed in that genus.

The cone-compressions called *Sporangiostrobus*, described by Bode (1928), and subsequently discussed more fully by Nemejc (1931), show interesting points of similarity with *L. zea*. The principal characters of the genus *Sporangiostrobus* are the very thick axis (which, from Nemejc's figures, seems to have occupied about three-quarters of the total cone diameter), and the sporangia, which were greatly foreshortened perpendicular to the cone axis. *Sporangiostrobus* also had long linear sporophyll laminas.

Lepidostrobus zea, in its rather broad axis and squat sporangia therefore resembles *Sporangiostrobus* in these features. But the axis of *L. zea* is only about half the total cone diameter, as against three-quarters for *Sporangiostrobus* ; and the sporangia of *L. zea*, although short, are none the less elongated perpendicular to the cone axis, whereas in *Sporangiostrobus* this is the shortest dimension of the sporangium. As a further distinction, the only megaspores obtained from *Sporangiostrobus* (*Triletes superbus* Bartlett) belong to the zonate group of *Triletes*, whereas those of *L. zea* (*Triletes auritus* Zerndt) are of the aphanozonate type (as interpreted by Dijkstra, 1946). For these reasons it seems preferable to place *L. zea* in the more generalized genus *Lepidostrobus* rather than greatly extending the limits of *Sporangiostrobus* to include it.

Comparison with other Species of Lepidostrobus.

In its relatively large axis, and its megaspore and microspore structure, *L. zea* is unlike any previously described species of *Lepidostrobus*. The cone described by Zeiller (1907) as *L. laurenti* is superficially similar to *L. zea* in its relatively large diameter and the considerable number of megaspores (probably several hundred) in each megasporangium. The cone is of Lower Carboniferous (Dinantian) age, and is in the form of a natural cast in a phosphate concretion. Nothing is therefore known of the details of the mega- or microspore structure. It differs from *L. zea* principally in having much larger sporangia, and a correspondingly narrower axis. Arnold (1950, p. 76) records that " spores resembling *Triletes auritus* were noted between the sporophylls of *Lepidostrobus bartletti* ". This species

has the structure of a typical *Lepidostrobus*, the cone being about 2·5 cm. in diameter with a relatively narrow axis. The megaspores are known only in section so that comparison between them and *T. auritus* is limited. Apart from the similarity of the spores, there is no great likeness between *L. bartletti* and *L. zea*.

There is unfortunately no clear-cut evidence as to the parent tree that bore *L. zea* : but the specimen from Ayrshire has associated with it on the same piece of shale, a large fragment of the bark of *Asolanus camptotaenia* ; and near the base of the holotype of *L. zea* there is an obscure fragment of what may also be the same species (Text-fig. 1, ? A.c.). Since there is only one convincing record of association in the four specimens of the species, there is not sufficient evidence to draw any definite conclusions as to the relationship between *L. zea* and *Asolanus*.

The Megaspores of Lepidostrobus zea.

Megaspores were obtained from the holotype, from the cone from Ayrshire, and from the isolated megasporangia from Yorkshire. Spores were removed from the specimens with a needle, macerated with Schulze's solution, followed by ammonia solution, and mounted in balsam. The number of spores removed, mounted and measured, and their respective size-ranges are given below. The measurement made on each flattened spore was the greatest diameter shown, where the outline had been distorted from the circular. The mean of these measurements (the " mean greatest diameter ") is given for each population :—

From the holotype : sixty-one spores, mean greatest diameter 822μ, range 673–1024μ (Plate II, fig. 2, Text-figs. 2a, b, d).

From the Ayrshire cone : eight spores, mean greatest diameter 636μ, range 520–710μ (Plate II, fig. 3).

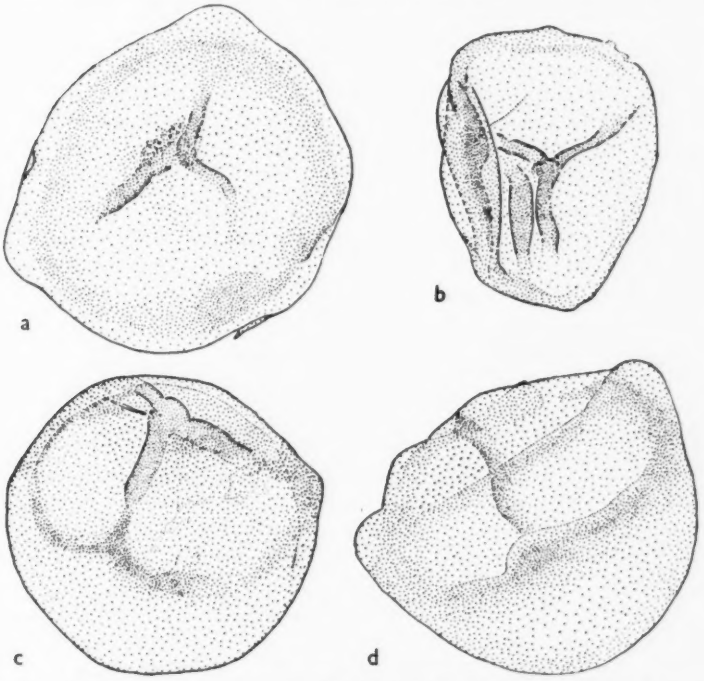
From the isolated megasporangium from Yorkshire : twenty-nine spores, mean greatest diameter 800μ, range 673–890μ (Plate II, fig. 4, Text-fig. 2c).

The smaller diameter of the spores from the Ayrshire cone may be due to physiological causes. Bochenski (1936) and others have shown that a comparable and even greater range of megaspore size can occur within the population of one cone. All the variation in form (e.g. degree of development of the ear-like flaps) shown by the Ayrshire cone and the isolated megasporangia from Yorkshire can be matched in the megaspore population of the holotype (cf. Plate II, figs. 2–4, Text-fig. 2a–d).

The megaspores from *Lepidostrobus zea* show a considerable degree of variation in the development of the ear-like flaps opposite the triradiate ridges. Such a range of development has already been included

in *Triletes auritus* by Dijkstra (1946) ; but none of the spores from *L. zea* show the extreme development of these flaps figured by Zerndt (1930, pl. 1, figs. 4 and 5). These two spores of Zerndt may be regarded as extreme forms, and the figures of Zerndt (1940) may be accepted as more typical of the species. Arnold's figures of *T. auritus* also agree well with the spores from *L. zea* (Arnold, 1950).

The mean size of the *L. zea* megaspores agrees with that given



TEXT-FIG. 2.—2a–d.—Megaspores (*Triletes auritus*) from *Lepidostrobus zea* sp. n. Figs. a, b, and d from the holotype. Fig. 2c from one of the isolated megasporangia from Yorkshire. (Kidston Collection, slide nos. 4839a, 4838s, 4839a, and 1273a respectively.)

by Zerndt (1930) in the type description of *T. auritus*, and the range in size is only slightly greater than the ranges given by Dijkstra (1946) and Arnold (1950) for that species. Of the two groups recognized by Zerndt within *T. auritus* (cf. Dijkstra, 1946, p. 33) the megaspores of *L. zea* seem to agree with the species rather than the " var. *major* ".

Some of the smaller examples of megaspores from *L. zea* in which the ear-like flaps were poorly developed or lacking (cf. Plate II, fig. 4) are remarkably similar to some spores figured by Arnold (1950, pl. 12, figs. 5 and 6), and assigned to *Triletes fulgens* Zerndt. These

American spores do, in fact, show a slight equatorial expansion opposite the tri-radiate ridges, which is a feature lacking in Zerndt's original figures of *Triletes fulgens* (Zerndt, 1937, pl. 1, figs. 1–9). It may also be significant that Arnold only obtained these few specimens of "*Triletes fulgens*" from one locality, from which he also obtained typical *T. auritus*. In view of the range of form in the spores from the *L. zea* holotype, it is possible that Arnold's spores may in fact be only small specimens of *T. auritus* and not *T. fulgens*.

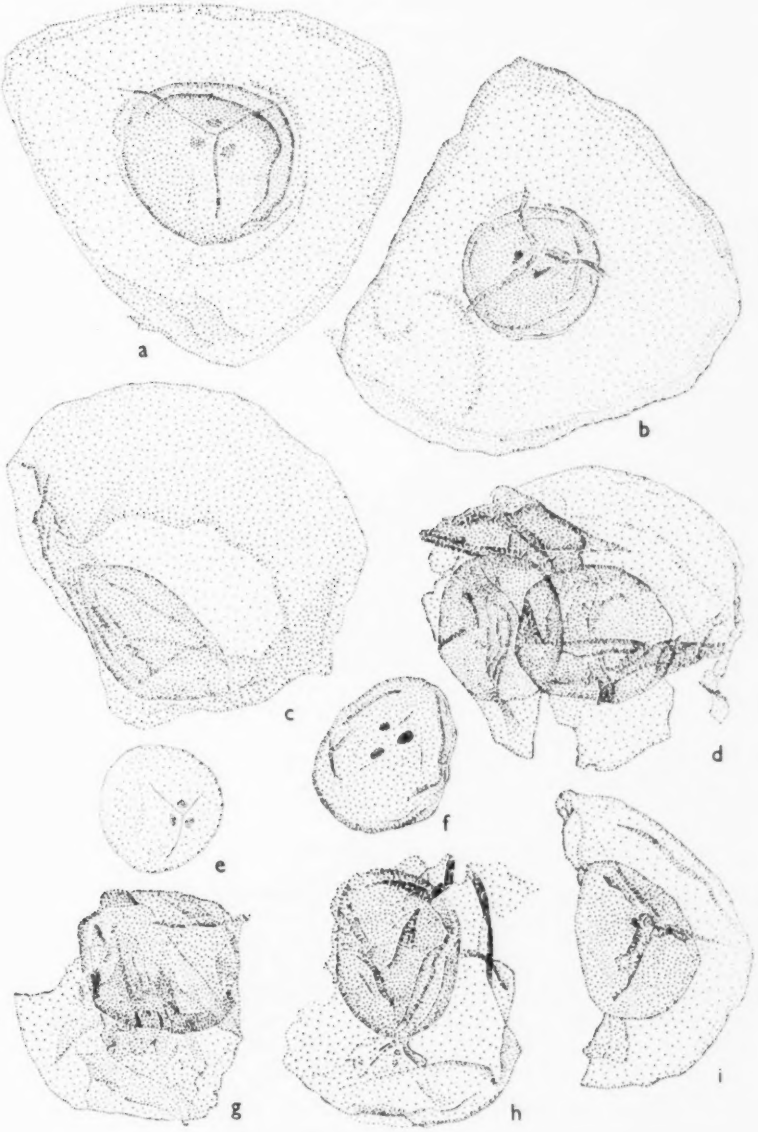
Part of the holotype of *L. zea* had evidently become impregnated with calcite and silica before the cone became compressed and fossilized. This area shows white in Plate II, fig. 1, the megaspores showing as silhouettes against the petrifying minerals. The megaspores from this region, freed from the calcite and silica by treatment with hydrochloric—followed by hydrofluoric acid, were unflattened. They could be most effectively studied by reflected light as solid objects, with a binocular microscope. These spores are more or less tetrahedral in form, and are not flattened and saucer-shaped, as are certain other members of the aphanozonate group of *Triletes*, before crushing (e.g. *Triletes mamillarius* sensu Dijkstra ; cf. reconstruction of Schopf *et al*, 1944, pl. i, fig. 2a).

The Microspores of Lepidostrobus zea.

The inter-radial papillae on the central body of the microspores, mentioned in the diagnosis, can be seen on Plate II, fig. 5, and Text-figs. 3a and b. But in some cases they cannot be recognized (cf. Text-fig. 3i), and this is probably due to their incomplete development, or to their being obscured by the decoration of the air-sac. The thickened margin of the air-sac is similarly not always visible.

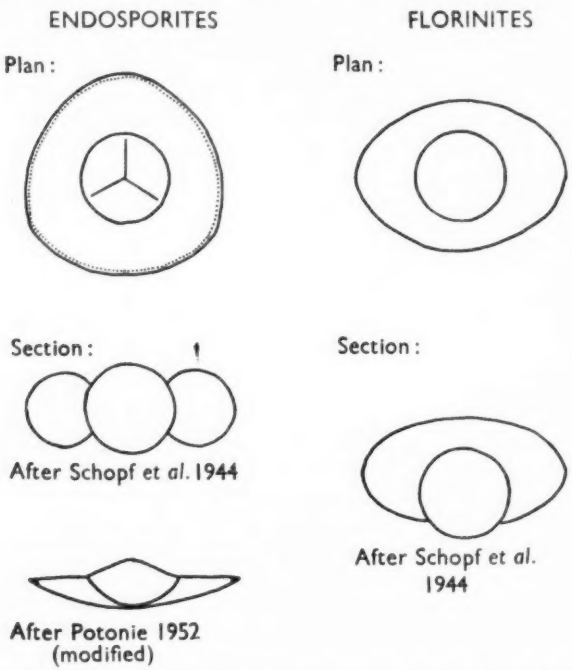
In those cases where the central spore-body has become isolated from the surrounding air-sac (Text-fig. 3e, f) the only features usually visible on the spore-body are the inter-radial papillae ; but occasionally the spore-body also shows the tri-radiate sutures (Text-fig. 3e). These are probably present in the spore-body as a set of actual or incipient slits, as well as being represented by a corresponding set of ridges or lips on the air-sac.

Two very different reconstructions of *Endosporites* have been postulated by Schopf *et al* (1944) and Potonié (1952) (Text-fig. 4). The evidence from the microspores of *L. zea* supports Potonié's interpretation rather than Schopf's ; but, for the microspores of *L. zea* (i.e. *Endosporites globiformis*), I would add to Potonié's reconstruction a slight thickening of the margin, where the proximal and distal faces of the air-sac meet. This feature is original, and not due simply to folding, because the thickened margin can still be recognized even when displaced from the periphery, in spores which have been flattened



TEXT-FIGS. 3a–i.—Microspores (*Endosporites globiformis*) from *Lepidostrobus zea* sp. n., showing various stages in loss of the air-sac. Figs. a–c, f, and i from the holotype; the remainder from the Ayrshire specimen. (Kidston Collection, slide nos. a–c 4838i; d and g 1573h; e 1573a; f 4838h; h 1573e; i 4838e.)

obliquely. Although Potonié does not discuss this marginal thickening, it appears in his plate 9, fig. 5. It is probable that the air-sac is free from the distal face of the spore-body : this is shown to be the case both by folds in the air-sac passing behind the central body, leaving it unaffected (as Potonié has pointed out) and also by the spore-body sometimes occurring displaced from the centre of the flattened spore, when the proximal face of the air-sac is torn, whereas the distal face



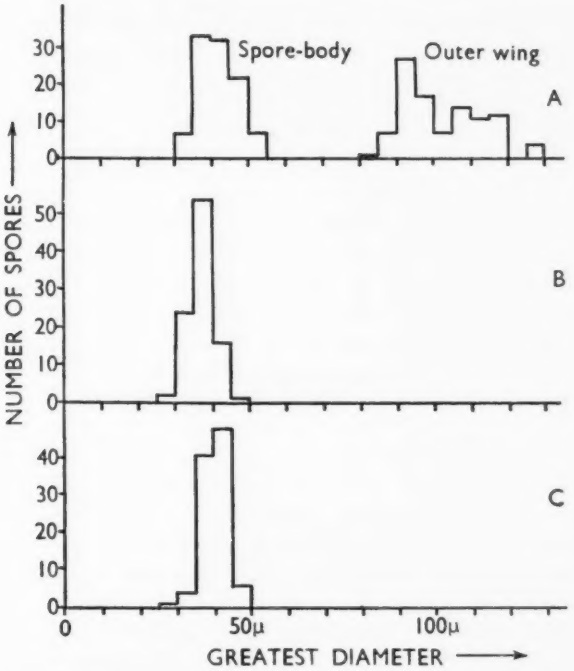
TEXT-FIG. 4.—Reconstructions of *Endosporites* and *Florinites*. In the vertical sections the proximal face (that in contact with the sister-cells of the tetrad) is uppermost.

is left intact (Text-fig. 3c). The spore must also have had an originally rather flattened form, since the spore-body is usually seen in the centre of the crushed spore, and is only rarely seen displaced from this position.

Fragments were removed from five microsporangia in the holotype from Yorkshire, and all yielded considerable numbers of closely similar spores. In some cases the outer air-sac was damaged or torn, and in others it was missing entirely (Text-figs. 3c and f). Histogram A in Text-fig. 5 shows the size-variation of 100 spores from one sporangium from the holotype ; the left-hand histogram represents

the central-body diameter, the right-hand, that of the air-sac. The greater spread of the diameters of the latter is probably due to crumpling.

The spores from the Ayrshire cone were apparently less well preserved, for, of the large number of spores obtained from three



TEXT-FIG. 5.—Histograms of size variation in microspores of *Lepidostrobus zea* sp. n., each based on measurements of the greatest diameter of 100 spores. Histogram A : spores from the holotype, with the air-sac intact. Left-hand part, central body diameter ; right-hand part, diameter of the outer wing. Histogram B : spores from the holotype, lacking the air-sac. Histogram C : spores from the Ayrshire cone, lacking the air-sac. (A and B, based on Kidston Collection, slide no. 4838i : C, on slide no. 1573a.)

fragments removed from the cone, the majority consisted only of the central body, and relatively few had retained even fragments of the air-sac (Text-figs. 3d, e, g–i). All the spores had an air-sac at one stage, since the isolated spore-bodies frequently show the inter-radial papillae, and occasionally the tri-radiate ridges present in the intact spores. Measurements of the isolated spore-bodies from the holotype from Yorkshire, and from the Ayrshire specimen also show closely similar histograms : histogram B on Text-fig. 5 is based on 100 isolated spore-

bodies from the holotype, and histogram C on an equal number from the Ayrshire specimen. The loss of the air-sac in the majority of the spores from the Ayrshire cone may be due to poor preservation or to damage resulting from over-maceration or both.

Synonyms of Endosporites globiformis (Ibrahim).

Spores closely similar to those of *L. zea* have been described under several different names, without adequate comparison being given. On the basis of existing figures and descriptions, the following species are indistinguishable from the microspores of *L. zea*, and either fit within the size range of spores from the holotype, or overlap it to a considerable extent. The microspores of *L. zea* are therefore identified with the first proposed name :—

Endosporites globiformis (Ibrahim, 1932, pl. 14, fig. 5). Ibrahim's figure is rather diagrammatic.

Endosporites globiformis (Ibrahim) Potonié, 1952 (pl. 9, fig. 5). This photograph is of a spore from the " type " coal seam for the species.

Endosporites zonalis (Loose, 1934, pl. 7, fig. 5).

Endosporites zonalis (Loose) Balme and Butterworth, 1952, pl. xlviii, figs. 5a–c.

Endosporites ornatus Wilson and Coe, 1940, p. 184, fig. 2. The line drawing of these authors does not, of course, show the air-sac texture, but this is indicated in the text.

" ? *Endosporites ornatus* Wilson and Coe " Cross, 1947, pl. v, fig. 181. This photograph shows the characteristic air-sac decoration.

Endosporites formosus Kosanke, 1950, pl. 7, fig. 9.

Endosporites vesicatus Kosanke, 1950, pl. 7, fig. 8. Although Kosanke regards these two species as distinct, there seem to be no reliable criteria on which they can be separated.

The " C1–C4 Series " of Crookall and Morris, 1952. Several of the spores figured by these authors show the inter-radial papillae, cf. pl. vi, figs. 1, 2, and 4.

The spores described by Crookall and Morris in their C1–C4 series show a considerable range in the ratio " air-sac diameter : spore-body diameter ", from 36–72 per cent. The spores from the holotype of *L. zea* show a smaller range of 31–57 per cent (mean value 41 per cent for 100 spores measured). The majority of the *L. zea* spores are therefore closer to the C1 rather than the C4 end of the series (in having the ratio less than 50 per cent). It seems that as Crookall and Morris suggest the C1–C4 series may represent more than one species, the spores of which cannot at present be distinguished.

The Affinity of the Spore-genus Endosporites.

Schopf *et al* (1944, p. 45) state that "*Endosporites* is related to some of the Pennsylvanian Cordaitaleans". This statement is made, apparently, on the basis of association of *Endosporites* with cordaitalean leaves, and also on the basis of "spores recorded by Wilson in male (cordaitalean) strobili". However, Professor Florin (in Crookall and Morris, 1952, footnote, p. 66) states that "contrary to what is said by Schopf and others, I do not think that there are any *Cordaianthus* species with the *Endosporites* type of pollen".

Crookall and Morris (1952) mention the occurrence of spores of the C1–C4 series in a preparation made by Professor Walton from a *Cordaianthus* compression. Professor Walton has been kind enough to let me examine his preparations, and these contain in all only twenty-one spores. Two of these are only 50μ in diameter, and are typical *Planisporites*: of the remaining nineteen spores, seventeen consist of a single thin-walled sac (conceivably an isolated air-sac minus the spore-body), and only two show a central spore-body surrounded by an air-sac. Even these are more like *Florinites* than *Endosporites*, since they are oval in outline rather than circular or triangular, and lack tri-radiate ridges. This *Cordaianthus* compression therefore has no bearing on the affinity of *Endosporites*.

The microspores of *L. zea* show that undoubted *Endosporites* were borne by a heterosporous lycopod. Another species of spore, at one time assigned to *Endosporites*, has subsequently been shown to have been borne by *Spencerites*, a lycopod cone (Chaloner, 1951). It therefore seems unwise to assign the remaining species of *Endosporites* to the cordaitaleans without further evidence.

I should like to express my thanks to Dr. C. J. Stubblefield, F.R.S., for help in granting me access to the Kidston Collection material; to Professor T. M. Harris, F.R.S., for help and criticism, and to the Department of Scientific and Industrial Research, from whom I have been in receipt of a grant during the course of this work.

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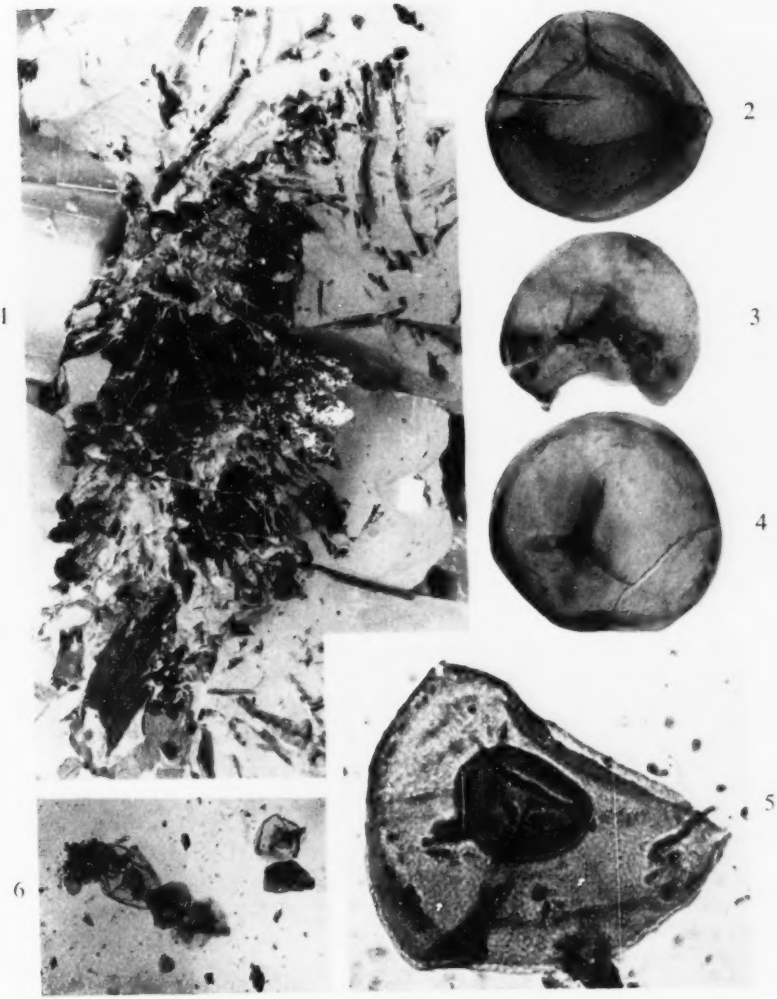
EXPLANATION OF PLATE II

All the numbers of slides and specimens refer to the Kidston Collection, Geological Survey and Museum, London.

FIG. 1.—The holotype of *Lepidostrobus zea* sp. n., photographed under paraffin oil, × 4/5. No. 4838.

FIGS. 2–4.—Megaspores (*Triletes auritus*) from *Lepidostrobus zea* sp. n., photographed by transmitted light, all × 40. Fig. 2, from the holotype (slide no. 4838r); Fig. 3, from Ayrshire specimen (slide no. 1573m); Fig. 4, from one of the megasporangia from Yorkshire (slide no. 1273a).

FIGS. 5 and 6.—Microspores (*Endosporites globiformis*) from the holotype of *Lepidostrobus zea*, stained with safranin and photographed with a green filter. Fig. 5, × 400. Fig. 6, a group of spores, two of which have lost their air-sacs, × 80. (Both from slide no. 4838i.)



A NEW SPECIES OF *LEPIDOSTROBUS*.

Facies Changes versus Sliding : Loch Leven, Argyll

By E. B. Bailey

As is well known the northern face of Garbh Bheinn, which rises from Loch Leven east of Caolasnacon farm, is occupied by a "very obvious asymmetric downfold" of inverted Eilde Quartzite (Hardie, 1952, p. 273 ; Bailey, 1934, p. 485). The inversion is established by current bedding and is unquestioned. The Eilde Quartzite here floats on Eilde Schist, younger than itself. The occurrence marks the western end of the Kinlochleven Inversion, one of the most remarkable geological structures known to science.

1. It has always been self-evident that the two named formations are linked by interbanding at many exposures of their junction, and that they are affected by local changes of character or facies. In fact any boundary drawn to separate them on a map is most unlikely to adhere for long strictly to one horizon. There are also striking discrepancies between the development of the assemblage made up of quartzite, banded schist, and schist as seen in neighbouring exposures. For my own part I have in general refrained from assigning particular discrepancies to original sedimentation, on the one hand, or to tectonic rearrangement on the other. Still, as Hardie correctly recalls (1952, p. 281) : "In offering an explanation for the fact that there is a smaller thickness of Eilde Quartzite in the north-eastern limb of the Garbh Bheinn downfold than in the south-western limb, Bailey (1934, p. 485) said that 'it is probable that there has been some sliding'. It is now suggested," Hardie continues, "that this difference in thickness may be largely or even wholly explained by underground continuation of the above-mentioned facies change." In other words, he thinks that much of what is called Eilde Schist in the north-eastern limb of the downfold passes during a short journey underground into what is called Eilde Quartzite in the south-western limb of the same. According to Hardie's measurements this leads to "possibly about 100 feet" of quartzite in the north-east (at U in his map, Text-fig. 1 and Table I, 1952, pp. 274, 279), swelling to "at least 450 feet" in the south-west (at Z)—though the downfold is of open character, and the total width of the outcrop of folded quartzite less than half a mile. I confess to surprise that anyone should think rapid facies change a more probable explanation of this particular variation than mechanical rearrangement. I note, however, that Hardie himself realizes that his guess has very little basis in observation. Speaking in justification of "the above-mentioned facies change" he can only say : "Although the very poorly exposed nature of the ground makes it impossible to observe such a facies change directly, there are a

number of lithological observations which, whilst not proving its existence, at least increases its probability" (1952, pp. 280–1).

2. In like manner Hardie goes on to offer purely sedimentary explanations of four other phenomena in the same general district. The first of these concerns the north-eastern outcrop of Eilde Schist, which borders the Garbh Bheinn downfold of Eilde Quartzite. This is followed by Binnein Quartzite, the next younger member of the stratigraphical succession, still upside down. On the south side of the loch the thicknesses of both Eilde Schist and Binnein Quartzite vary dramatically along their adjacent outcrops. In about half a mile, according to Hardie's measurements, the Eilde Schist swells from 600 feet to 1,700 feet, while the Binnein Quartzite concurrently shrinks from 1,000 feet to nearly nothing (1952, p. 282). Hardie reaches the amazing conclusion that: "The only theory which fits the facts reasonably well is to regard the top of the Eilde Schist as an erosion surface." Once again, however, he frankly confesses that his solution is no more than a guess. "It must be admitted," he says "that although there are more or less continuous exposures along the shore of the loch from the Eilde Schist into the Binnein Quartzite, the exact position of the disconformity is still in doubt" (1952, p. 283).

3. The north-westerly outcrop of Eilde Schist, which bounds the Eilde Quartzite downfold, is also followed by Binnein Quartzite, but here the succession is right way up. On the north side of the loch this Binnein Quartzite very quickly ceases, leaving merely some banded mica-schist and quartzite to mark for a time the junction of coalescent Eilde Schist and Binnein Schist. (The full stratigraphical succession is Eilde Schist, Binnein Quartzite, Binnein Schist.) After carefully examining the exposures I have ventured to say that "the northward disappearance of the Caolasnacon [outcrop of Binnein] quartzite is probably due to sliding, though possibly to mere stratigraphical thinning" (1934, p. 479). I prefer this non-commital judgment to Hardie's confident inference from the same exposures. He tells us that he "has recently discovered yet another example of a facies change. When traced in a north-easterly direction it was found that the massive white quartzite develops intercalations of schist, which rapidly thicken at the expense of the quartzite, so that in the space of a few hundred yards the entire Binnein Quartzite is represented, not by quartzite but by schist" (1952, p. 283).

4 and 5. The next two localities can easily be identified in Hardie's description (1952, p. 284). I have mapped slides at both of them, in one case between Eilde Quartzite and Eilde Schist, in the other between Binnein Quartzite and Binnein Schist. Hardie takes it for granted that these two slides are hypothetical, and says he expects to replace them, in the first case by a sudden facies change, in the

second by an erosion surface. Here he has completely misunderstood my presentation of the evidence (1934, pp. 489–490, 491). These particular slides are not hypothetical, but have been established by attention to current bedding. At the first of them Eilde Quartzite youngs away from adjacent younger Eilde Schist. At the second, Binnein Quartzite youngs away from adjacent younger Binnein Schist.

My impression on reading Hardie's paper is that he is certain that if there is a slide he will be able to identify it with some belt of obviously broken rock. He seems to be in the position firmly held by that supreme observer Clough some forty years ago. It is well to remember that Clough changed his mind after realizing that he had mapped the Ballachulish Slide in the Windows of Etive for about a mile without for a moment suspecting its existence. The term "invisible slide" has occasionally crept into the literature from the backchat of geologists in the days of auld lang syne. It has sometimes been used to express derision, sometimes sheer wonder. It should not be forgotten.

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Facies Changes versus Sliding—A Reply

By W. G. Hardie

In my recent paper on the Lochaber Series (Hardie, 1952), I gave detailed facts about the lithology of several of the stratigraphical units, and I concluded that the remarkable thickness variations were due to original sedimentary processes rather than to mechanical rearrangement. Sir Edward Bailey, in his paper in this current number of the *Geological Magazine*, strongly disagrees with my views, and argues in favour of sliding. In reply I would like to make the following three points.

(1) According to me (1952, p. 283), the north-easterly disappearance of the Caolasnacon outcrop of the Binnein Quartzite, north of Loch Leven, is due to a facies change, but Sir Edward prefers a non-committal judgment on the same exposures and reaffirms his earlier statement that the change is due either to sliding or to stratigraphical thinning (Bailey, 1934, p. 479). Sir Edward courteously sent me a typescript of his intended paper when I was staying in Glencoe, and I was able immediately to revisit this critical area. I returned from it still firmly convinced that a facies change is present and that, in this case at least, sliding is unnecessary to explain the facts.

Further observations relating to this area are as follows. Omitting for a moment the Binnein Quartzite immediately adjacent to the Binnein Schist, I maintain that it is self-evident that, starting from undisputed Binnein Quartzite, and passing in a north-easterly direction, the lithology of the excellent exposures shows a progressive change from massive white quartzite, through banded quartzite and schist into schist containing insignificant quartzose ribs. I also maintain that it is a fact that, concomitant with this lithological change, the beds become very much crumpled. It is my opinion that these changes take place along the strike of the beds ; in other words a facies change is present. As regards the Binnein Quartzite immediately adjacent to the Binnein Schist, the exposures towards the north-east are too scattered to allow one to draw the same confident conclusions. After an initial sigmoidal change of strike, it is a fact that the massive white quartzite is last seen striking towards scattered exposures of schist several hundred yards away. In thinking that it is reasonable to conclude that the disappearance of this part of the quartzite is also due to a facies change, I am, of course, influenced by the much more visible evidence of the adjacent area first mentioned.

(2) Sir Edward is surprised at my claim that a rapid facies change exists between the Eilde Quartzite and Eilde Schist on Garbh Bheinn,

south of Loch Leven, and criticises me for drawing such a conclusion from the badly exposed ground. My claim was that the evidence points towards a facies change, and is, at least partly, inconsistent with sliding. Regarding the rapid nature of my postulated facies change, I now emphasize that it is no greater than that which I claim for the Caolasnacon outcrop of the Binnein Quartzite, discussed above, where the exposures are so very much better. Before we can argue that facies changes of such rapidity are unreasonable in the Lochaber Series, we should need to know much more than we do about the environment in which it was deposited.

To return to my claim that the lithological evidence presented in my paper is, at least partly, inconsistent with sliding, it is necessary to consider the actual exposures of the junction. If sliding is present where the junction maps out as a diachronic line, then I should expect to be able to lay my finger on places where beds of quartzite end abruptly against beds of schist along an obliquely running line (the trace of the slide). Wherever the diachronic junction is exposed (the only exposures are south of Garbh Bheinn), however, the beds on either side are seen to be parallel. As I argued previously (1952, pp. 279–280), such exposures are understandable if the diachronic junction traverses an area where there is a rapid facies change.

This argument against sliding is, of course, only valid provided it is agreed that my junction (based upon lithological evidence) is coincident with Sir Edward's slide. Sir Edward would presumably think otherwise, since he would regard my boundary as being of purely local significance. On the south face of Garbh Bheinn Sir Edward's slide, which must still be diachronic if one is to take into account the continued southerly reduction in thickness of the Eilde Schist (Hardie, 1952, p. 280), would presumably avoid my junction exposure where the adjacent beds have the same dip and strike. In the fault intrusion outcrop I infer that Sir Edward would draw his slide parallel to the outcrop of the beds, and somewhat to the west of my diachronic junction.

(3) Sir Edward infers from my paper that I am labouring under the misguided belief that, if a slide is exposed, it can be identified by obviously broken rock. This is definitely not the case, and I had no intention of conveying such an impression. I am fully aware that slide tectonics are totally different from thrust tectonics, as Sir Edward has clearly stated (Bailey, 1938). Furthermore, under the guidance of Sir Edward himself, I have seen several exposures of both the Ballachulish and Fort William slides, including the famous Windows of Etive. I therefore do not expect to find crushing associated with sliding.

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Gravity Measurements in Durham and Northumberland

By J. Hospers and P. L. Willmore

Abstract

Gravity measurements in Durham and Northumberland in the region of the Alston Block are described, and their reduction as well as the accuracy of the results discussed. It is shown that the results between and near Newcastle and Durham are fully consistent with the conception of a horst, uplifted between the Ninety Fathom Dyke and the Butterknowle Fault. The observations along the valley of the East Allen, however, require an entirely different explanation. It is concluded that a closed area of negative anomalies occurs, centred near Wear Head. This is interpreted as due to a granite intrusion not yet exposed by denudation. The mineralization of the area is discussed and it is shown that it supports the foregoing interpretation.

I. Introduction

THE gravity measurements to be described here were carried out in 1950 at the invitation of the Department of Geology, King's College, Newcastle upon Tyne, with the object of determining whether observations of gravity could help to elucidate geological structures in Northumberland and Durham. In particular, it had been hoped that the course of the drift-filled valleys which cut into the coal measures could be traced in this way. Detailed considerations of the results to be expected from a well-known buried valley (The Wash) showed that the anomaly would be a small one, of the order of one or two milligal. If observations on The Wash were to be used to test the general applicability of the method great care would be required in eliminating the effects of the surface relief and of numerous small faults in the coal measures. Both of these features would tend to produce anomalies running roughly parallel to the relevant one, and the second would be extremely difficult to allow for unless the effect of each individual fault could be shown to be small.

To test the last possibility a line of observations was run from Newcastle along the Ponteland road, where it crosses the Ninety Fathom Dyke. It was found that the gravity anomaly changed by about $3\frac{1}{2}$ mgal., and although the faults below The Wash are much smaller than the Dyke, effects proportional to the total throw would still be quite appreciable. Further consideration showed, however, as will be seen in Section III, that the observed gravity profile could not have been produced by the known change of density across this fault, and hence that some larger feature must also be present.

When the observations were discussed with members of the Geological Department of King's College, Professor Hickling suggested the following explanations :—

(1) That some of the observed effect might arise from a gradual

thickening of the glacial drift at the northern end of the gravity profile, and thus be of purely local significance.

(2) That if there was a large structure associated with the Ninety Fathom Dyke it would probably be a fault of pre-Carboniferous age. Such a fault, extended westwards, would pass almost through the northern end of the " Cross Fell Inlier ", in which pre-Carboniferous rocks are exposed at the surface. The area known as the Alston Block lies east of the Inlier and it is probable that the basement is relatively elevated over the whole region. The Alston Block (this name seems to have been introduced by Trotter and Hollingworth, 1928) is bounded on the south by the Stainmore depression and the Butterknowle Dyke, but its northern boundary is generally believed to be the Stublick system of faults (Hickling and Robertson, 1949). The present suggestion is that the Ninety Fathom Dyke, not the Stublick system, is the true boundary, even though the surface geology yields no evidence that the Dyke extends more than 20 miles from the coast.

To decide between these hypotheses a second line of observations was run across the Ninety Fathom Dyke between Newcastle and Gosforth. Although the result was not conclusive it tended to support the idea of a continuous major feature underlying the surface indication. The investigation of The Wash could only have proceeded if the effect of the Ninety Fathom Dyke had been less than 1 mgal. or if we had investigated a sufficient number of other faults to show that the anomaly over the Dyke was quite exceptional. The alternative was to delineate the cause of the anomaly which had been observed. The latter course was adopted, but this decision does not indicate that we consider the gravitational tracing of buried valleys to be impracticable, as we now believe that the Ninety Fathom Dyke is by no means typical of the faults in the coal measures. In the course of the measurements carried out to delineate the anomaly just mentioned we found the large negative anomaly centred somewhere near Wear Head. It is with this anomaly that this paper is mainly concerned.

II. Reduction of Observations

The instrument used was a small Graf gravimeter (Graf, 1942) carried in a padded box fixed to the floor of a small motor van by means of anti-vibration feet.

Each reading of the gravimeter yields a measure of the force of gravity acting on the instrument at a particular time, but the values are related to an arbitrary zero which is continually drifting. The zero is determined at least once during a day's work by taking a reading in a position where " g " is already known. The drift is eliminated by repeating observations at enough stations to show how the difference between readings at the same place varies with the time interval between

them. After the elimination of the drift the repeated observations show a residual scatter whose magnitude gives an indication of the reliability of work on that particular day. During the present study the drift was always less than 3 mgal. per day, and fell to about one-fifth of that value when the instrument had settled down after readjustments of its range and thermostat.

Under favourable circumstances the scales of the Graf gravimeter can be read to within 0·1 mgal., but this uncertainty may be trebled if the instrument is exposed to the shaking of wind or traffic. Non-linearity of drift may account for a further 0·2 mgal. of uncertainty, and it has recently been found that the orientation of the instrument in the magnetic field of the van may alter the reading by as much as 0·5 mgal. Experience with the reproducibility of station differences has, however, indicated that small differences of "g" remain consistent within a standard deviation of about $\pm$ 0·25 mgal. Large differences are affected by the uncertainty of calibration of the instrument (of the order of 1 part in 200, or about 0·75 mgal. over our extreme range).

The observations have all been connected to the pendulum base station in the Armstrong Laboratory of Physics, King's College, Newcastle, where the value of gravity is taken to be 981·50622 cm./sec.^{2} (Browne, *et al.*, 1950). The value of gravity to be expected from the latitude of each station (using the 1930 International Gravity Formula) has been subtracted from the observed value and the results further adjusted to allow for the elevation of the station and for the rocks above sea-level. These rocks were assumed to have a uniform density of 2·4 g./cm.^{3}, giving a correction of 0·0634 mgal./ft. for the combined effect of altitude and rock. An indication of the accuracy of this figure may be obtained by inspection of Text-figs. 2*a* and 2*c*, by noting the extent to which differences of height between neighbouring stations are smoothed out on the Bouguer anomaly curve. Much more elaborate corrections are customary in full-scale surveys, but these require a detailed knowledge of the densities of all the strata involved. Further corrections may be applied to allow for irregularities of the terrain close to the station. With the surface relief which has been encountered in the present work, the terrain corrections are never likely to have exceeded fractions of a mgal., whilst the uncertainty of density may introduce errors of the order of $\pm$ 2 mgal. Differences between neighbouring stations will, however, be much less than the latter value, and it is not considered that the errors involved in using the rough Bouguer corrections can invalidate any of the conclusions of this paper. For a more detailed discussion of the technique of gravimeter surveying the reader is referred to Cook and Thirlaway (1952, pp. 256–265).

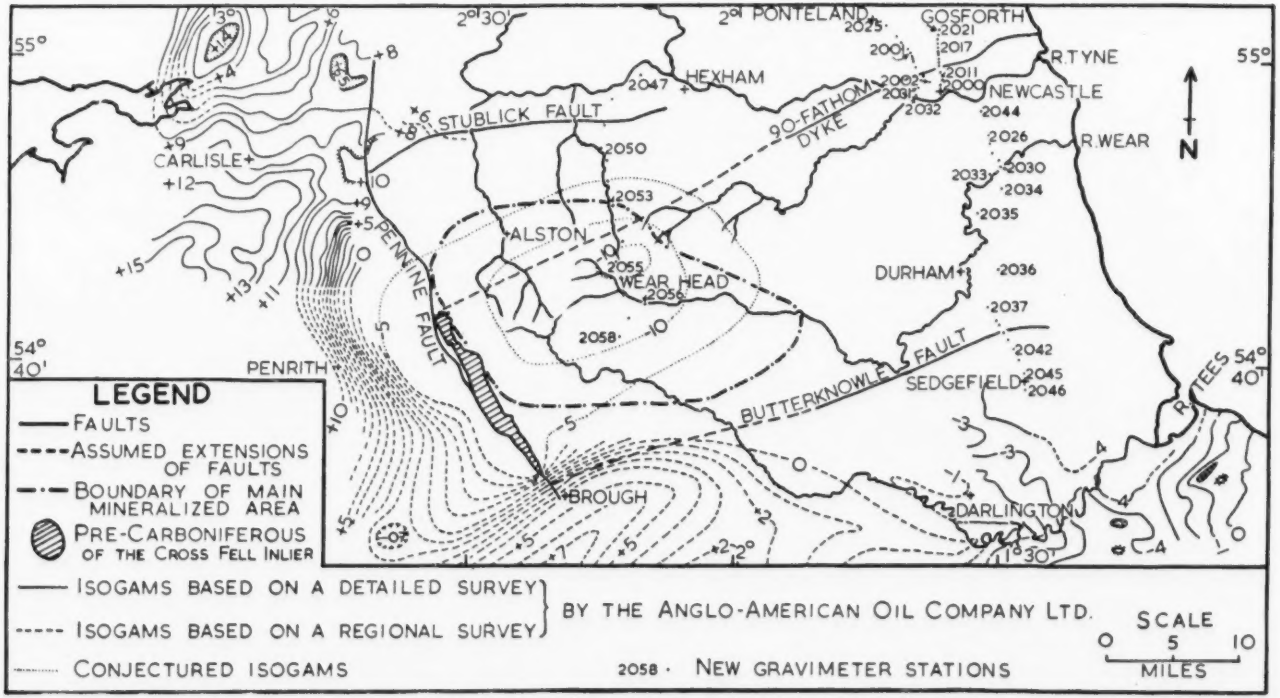
III. Interpretation

The stations occupied (numbered 2,000–2,058) are plotted in Text-fig. 1. The map also shows the isogams, based on surveys by the Anglo-American Oil Co. (White, 1948).

The first line to be investigated was the one across the Ninety Fathom Dyke, from King's College to near Ponteland. The Bouguer anomalies and elevations of the stations are plotted against latitude in Text-fig. 2*a*. The anomaly curve is of the type which would be expected to occur on passing over a fault and yields an order of magnitude for the scale of the geological structure. It may readily be shown (using the formula given by Nettleton, 1940, p. 113) that the anomaly produced by a buried half-plane of excess mass reaches half its extreme value on either side of the point of inflexion in a horizontal distance equal to the depth of the sheet, so that abrupt anomalies can only be produced by shallow structures. The converse is not strictly true, as gradual changes of gravity can be produced by lensing of quite shallow beds, but if the geological structure is known to introduce a sudden change of density across a steeply inclined fault-plane the depth of the major change of density is determinate. In the present case the depth suggested is 2,000 feet and the centre of the anomaly is about a mile north of the surface outcrop of the Dyke. As the known effect of this fault is to substitute predominantly shaly coal measures for those composed mainly of sandstone, all within less than 600 feet from the surface, there is no way in which the expected change of density can be made to explain all the observations. We therefore require the additional postulates of Section I.

Our second line was run along the Great North Road from Newcastle to Gosforth (see Text-fig. 2*b*). Here the change in gravity anomaly (approximately 2·6 mgal.) extended over an even greater distance and must therefore be caused by an even more deeply seated density contrast, although the known change in the coal measures near the surface was if anything more pronounced than along the Ponteland road. This result was interpreted as confirming the existence of the major buried structure and justified the commencement of the third part of the work.

Text-fig. 2*c* shows the results obtained along the line running south from Newcastle, where the anomalies tend to increase, down to approximately latitude 54° 46′, afterwards dropping sharply in the neighbourhood of the Butterknowle Fault. Still further south, the line runs into the region investigated by the Anglo-American Oil Co., and our measurements fit in well with the Company's observations around Darlington. This agreement between surveys tied to different base stations is most satisfactory but it is unfortunate that we failed to



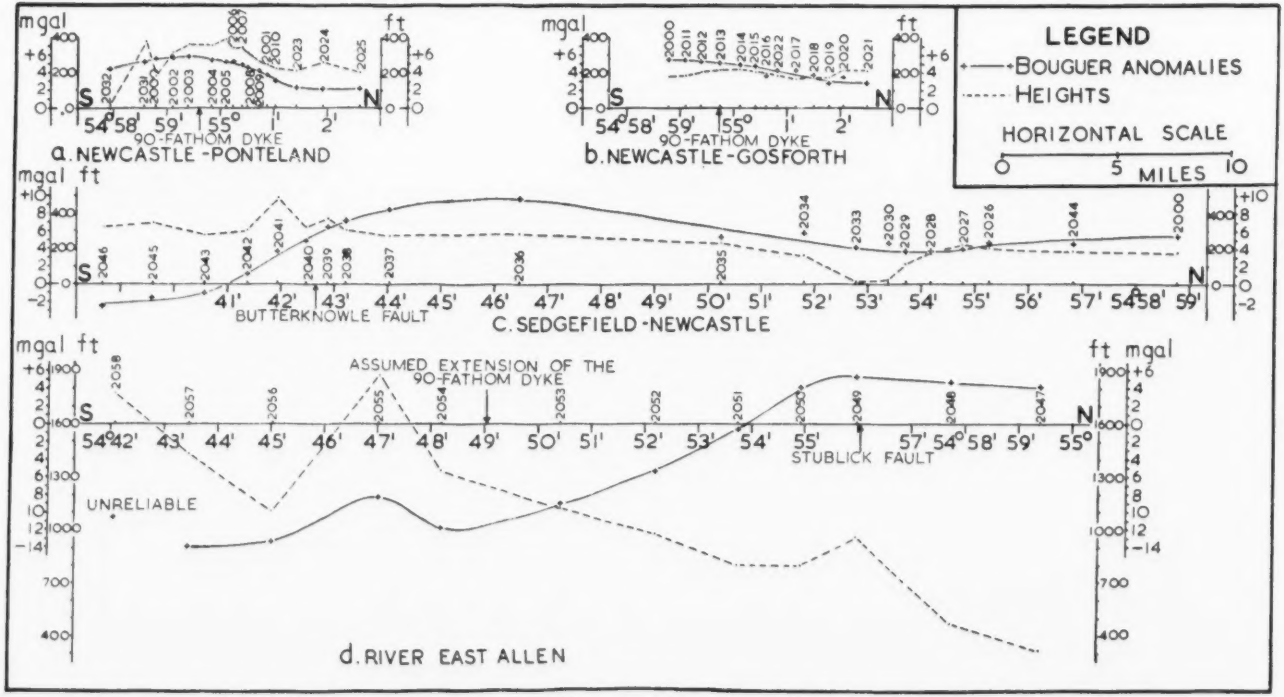
TEXT-FIG. 1.—Isogam and structure map of northern England. Isogams of the Anglo-American Oil Company, Ltd., from White (1948) Geology after Geological Survey maps and Hickling (1931, pl. 9). Boundary of main mineralized area after Dunham (1931, p. 276, fig. 30). Stations 2008 and 2009 between Newcastle and Ponteland are not shown on this map, but appear in Text-fig. 2*a*.

realize in advance that the other survey was so close to ours and that a definite connection was not made between them. Near the centre of the line stations 2,029 and 2,030 were placed in the region near Washington, where cindered coal is known to occur. Inspection of Text-fig. 2*c* will show that this feature is not associated with any large anomaly.

The results in this, the eastern part of the survey, are fully consistent with the suggestion that the region between the Butterknowle Fault and the Ninety Fathom Dyke forms a horst in which the pre-Carboniferous basement is uplifted with a gentle dip towards the north. This suggestion has recently been clearly stated by Hickling (Hickling and Robertson, 1949, p. 12). On the other hand, the observations along the valley of the East Allen (Text-fig. 2*d*) are by no means so easy to explain in terms of this assumed structure. Running south from the Tyne valley the gravity field is dominated by a pronounced negative trend in the Bouguer anomalies. This is associated with a general tendency for the stations to be on higher ground towards the south and it might be thought that the effect could arise from the isostatic compensation of the elevated mass. An estimate of the effect of isostatic compensation shows, however, that it could only account for 1·3 mgal. out of a total effect of 18 mgal.

The relation of the foregoing work to the results of the Anglo-American survey is shown on Text-fig. 1. The isogams show positive Bouguer anomalies to the west and south, with a strong negative trend centred somewhere near Wear Head. The positive anomalies along the Newcastle–Durham line and around Hexham indicate that the negative gradients must also run inwards from the north and east. Hence the observations require a closed region of negative anomalies which must extend about 25 miles from north to south and perhaps 30 miles from east to west. The observation at station 2,058 is marked as unreliable on Text-fig. 2*d* because of an accidental shock which may have disturbed the gravimeter at the time. The recorded value, however, fits well with the general picture and may be a genuine indication of the rise in gravity at the southern end of the basin.

The mass deficiency required to produce an anomaly with boundaries as abrupt as those observed must be within about 4 km. of the surface, whilst the geological evidence suggests that the pre-Carboniferous basement is relatively elevated within the area. One would expect the pre-Carboniferous rocks to have an average density exceeding that of the Carboniferous, resulting in a gravity "high" instead of a "low" as observed. It follows, therefore, either that the basement rocks are lighter than the surrounding Carboniferous or that they have been forced upwards or replaced by some material lighter than themselves. More work is evidently required to decide between



TEXT-FIG. 2.—Sections showing Bouguer anomalies and heights of stations plotted against geographic latitude.

these alternatives, but for the time being it seems that the first is the least likely, judging from the lithological character of the pre-Carboniferous as exposed in the Cross Fell Inlier. It is of importance in this connection that gravity measurements in Devon and Cornwall (Bullard and Jolly, 1936, p. 476), in Ireland (e.g. Thirlaway, 1951, Murphy, 1952, Cook and Murphy, 1952), and in North America (e.g. Romberg and Barnes, 1944, Woollard, 1948, p. 313) have shown that large deficiencies of gravity may be associated with intrusions of granite. This increases the probability of the second alternative considerably and we therefore suggest that the Alston Block area is underlain by a granite intrusion not yet exposed by denudation.

This receives support from a quite independent line of reasoning. Mineral deposits occur as fissure-veins in the Carboniferous rocks of the area under discussion. The principal ore-mineral is galena, but zinc-blende, fluorspar, barytes, and witherite have also been mined (Dunham, 1931). The map published by Dunham (1931, p. 276) shows the distribution of mineral veins in the North Pennines. The boundary of the main mineralized area is shown in Text-fig. 1. This area and the region of negative anomalies practically coincide. Dunham (1931, p. 280) has concluded that the North Pennine mineral deposits are of hypogene origin and in a later publication states, when dealing with their genesis in general, that " most investigators now regard the lead-zinc deposits, with very few exceptions, as having been deposited from solutions of deep-seated origin " (1950, p. 13). Wells (Wells and Kirkaldy, 1948, pp. 173–4) has gone one step farther and has written : " In the lodes (of Cornwall) the different minerals are arranged in zones concentric with the upper surface of the granite masses with which they are associated, this distribution depending upon the temperature of formation of the different ore-minerals. It is significant that a similar succession of zones has been established in the lodes of another English locality, the Alston Block of the Northern Pennines, where lead and zinc ores have been mined for upwards of ten centuries, nearly 600 metalliferous lodes having been discovered in this period. By analogy with Cornwall one is justified in inferring that the Northern Pennines are underlain by yet another granite, not yet uncovered by denudation. As the lodes cut Carboniferous, chiefly Yoredale, rocks and as some of the ore minerals occur as detrital grains in the basal Permian sediments, the hidden parent granite and the lodes must be Armorican."

It must be added that a Tertiary age for the mineralization of the Alston Block has been claimed as more likely (Trotter, 1944), but this does not affect the inference of the presence of a granite intrusion from the mineralization of the area.

It would be premature for us to draw any definite conclusions from

the details of the observations along the valley of the East Allen. The position of the major known faults may, however, be of interest and it should be noted that the Stublick Fault runs close to the extreme northern edge of the gravity basin. The assumed extension of the Ninety Fathom Dyke crosses well down on the anomaly curve, and is in fact fairly close to the point on the profile where the anomalies rise for a short distance. Inspection of Text-fig. 1 will show, however, that the general picture is as consistent with the idea of a small local " high " as with an extended anomaly running parallel to the fault. Finally, we note that the assumed extension of the Butterknowle Fault, just north of Brough, passes through the region of maximum gradient at the southern edge of the negative region, but whilst this type of anomaly is just what would be expected from a large fault, the direction of the gradient is the reverse of that found between Sedgefield and Durham.

It seems fairly clear that the southerly gradient at the eastern end of the Butterknowle Fault must diminish more or less steadily until it is replaced by the northerly gradient at the western end. For the Ninety Fathom Dyke it seems quite probable that the positive step from north to south might be maintained over the entire length. The interpretation cannot be pushed much further, for without accurate densities we can assign neither magnitude nor direction to assumed changes in the level of the underlying strata.

IV. Conclusions

(1) The observations of gravity across the eastern part of the Alston Block are fully consistent with the idea that the 20-mile block between the Ninety Fathom Dyke and the Butterknowle Fault forms a definite horst, in which the pre-Carboniferous is uplifted.

(2) The observations across the western part point to the presence of a large acid intrusion, which has not yet been exposed by denudation. This receives support from a consideration of the mineralization of the area.

V. Acknowledgments

We should like to express our appreciation of the hospitality and assistance which was extended to us by Professor S. Westoll and the members of his department. In particular, the planning of the experiments was determined largely in the light of the geological advice of Professor H. G. A. Hickling, whilst the enthusiastic assistance of students and others substantially lightened our task in the field.

We wish to thank the Royal Dutch Shell Group of Oil Companies for a Studentship (J. H.) and the Imperial Chemical Industries for a Fellowship (P. L. W.), during the tenure of which the foregoing work was carried out.

Our thanks are also due to Mr. B. C. Browne, Head of the Department of Geodesy and Geophysics, Cambridge, for reading the manuscript and for helpful criticism.

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Gravity Measurements over the Northern Pennines

By M. H. P. Bott and D. Masson-Smith

Abstract

Gravity measurements over the Northern Pennines indicate the presence of a buried acid intrusion under Upper Weardale, from which the mineralization there has originated. The negative Bouguer anomaly is presumed due to direct density contrast between the acid intrusion and the country rock, and is consistent with a magmatic origin.

I. Introduction

TO attempt to elucidate further the deep structure of North-East England, and in continuation of earlier gravity traverses (Hospers and Willmore, 1953) about 900 gravity stations covering parts of Northumberland and Durham were taken during summer 1952, supported by 1,000 vertical field magnetic observations. Neither field work nor interpretation is yet complete, and this is only a preliminary account of the most obvious gravity feature. The Graf gravimeter of the Department of Geodesy and Geophysics, Cambridge University, was used throughout.

II. The Negative Gravity Anomaly over Upper Weardale and its Significance

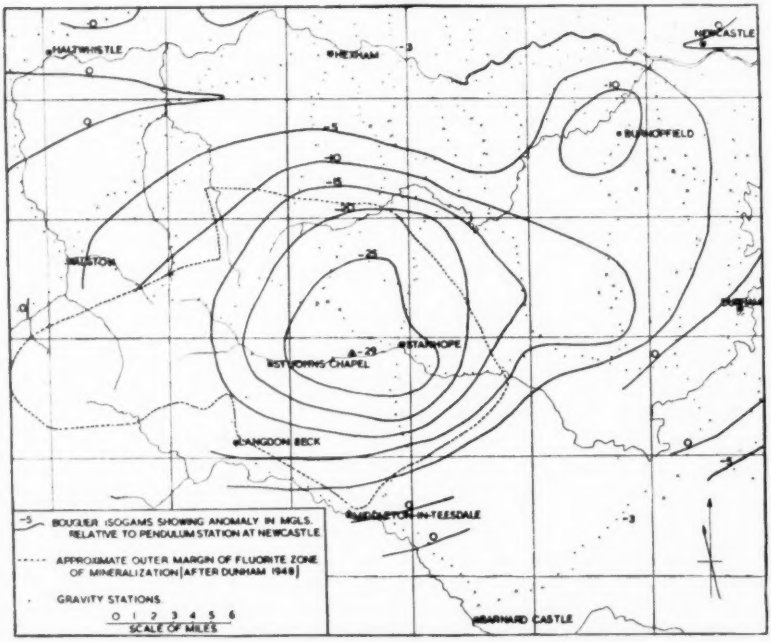
A closed and east–west elongated area of negative Bouguer anomalies was outlined over the Northern Pennines. The maximum negative anomaly over the background value is nearly − 30 mgals., and this is in Weardale, between Stanhope and St. John's Chapel. A second low, of − 11 mgals., occurs over Burnopfield, and is connected to the main negative anomaly by a saddle. A sketch-map of the anomalies shows also the fluorite zone of mineralization (Dunham, 1948), Text-fig. 1. Terrain corrections have not yet been made, but the error introduced by this and similar causes is usually well below 2 mgal. Isostatic adjustment can only account for a small fraction of the anomaly (Hospers and Willmore, 1953).

By integrating the main anomaly over the surface it is calculated that the mass deficiency lies between 5×10^{17} gms. and 7×10^{17} gms. Between Stanhope and Middleton-in-Teesdale the maximum gradient reaches about 8 mgals. per mile, which is extremely high, and means that the anomaly cannot be of deep-seated origin and must be caused by direct density contrast between lighter and denser masses of rock. If the upper surface of the lighter rock were 5,000 feet deep the density contrast would be greater than 0·1 gms./c.c., perhaps 0·2 gms./c.c., and the floor of the order of 30,000 feet. The contact would be steep. However, the surface ot the lighter rocks could lie anywhere between the ground and more than 5,000 feet depth, and hence it is necessary to

consider the possible explanations geologically. Four possibilities are investigated below and the fourth, namely an acid intrusion, is definitely preferred.

(i) *A Trough of Less Dense Devonian and/or Lower Carboniferous Deposits.*

Assuming such deposits to be 0·2 gms./c.c. less dense than the surrounding rocks, the basin would be at least 14,000 feet deep in the centre. It is likely that the density contrast would be less, for although



TEXT-FIG. 1.—Gravity survey of the Northern Pennines.

he Old Red Sandstone density at Hay, in South Wales, is 2·54 gms./c.c. (Cook and Thirlaway, 1952), the lithology here is different from that of the O.R.S. of Ireland and Scotland, where sandstones and conglomerates predominate in the sedimentary phase. Based on fifteen samples, which may not be random, the O.R.S. of Ireland appears to have density 2·69 ± 0·04 gms./c.c. (Cook and Murphy, 1952, based on Jackson, 1951). This is not far below the generally assumed Lower Palaeozoic densities of 2·70–2·80 gms./c.c. Hence an O.R.S. trough would have to be very deep for its areal extent. Furthermore, there is still a negative anomaly of about − 15 mgals. over background value at Langdon Beck Hotel, with an apparently low gravity gradient in all

directions. Langdon Beck Hotel is within a mile of the Teesdale inlier, where undoubted Lower Palaeozoic or earlier rocks outcrop (Gunn and Clough, 1878).

(ii) *Less Dense Pre-Devonian Rocks.*

This is also considered unlikely, for such large density contrasts are not usually observed in Lower Palaeozoic rocks of Britain except in weathered specimens, and if they did occur neither deposition nor earth movements would be likely to concentrate a peculiar lithological phase in such a well defined and steep-sided basin.

(iii) *A Salt Dome.*

A salt dome would have to be unprecedentedly large to give the negative anomaly observed. There is no geological evidence for salt and this possibility is considered unlikely.

(iv) *An Igneous Intrusion of Acid or Nearly Acid Composition.*

There is contributory evidence for this hypothesis in that the gravity anomalies roughly coincide in extent, shape, and position of centre with the mineralization zones (Dunham, 1948). It is also clear that the geographical distribution of mineral deposits depends partly on stratigraphical horizon, the Lower Carboniferous limestone being most receptive. No thermal metamorphism has been detected at the surface but the aureole of an intrusion of this size need not be as thick as 5,000 feet. There is also a slight doming which can be seen on the Great Limestone contour map (Dunham, 1948).

It is concluded that there is no geological evidence against this hypothesis ; moreover negative anomalies seem usual over known granites.

The existence of the second low around Burnopfield correlates with the presence of barium chloride in ground waters reached in coal mines of north-east Durham and the extreme south of Northumberland, which may have originated from mixing of hydrothermal solutions and ancient ground-waters (Dunham, 1948, p. 117). It is presumed the intrusion comes near the surface again in the vicinity of Burnopfield.

The slight surrounding positive anomaly may be due to the denser stoped block, but this is as yet very uncertain.

III. Deductions from Results

(1) From the above discussion it is assumed that the negative Bouguer anomaly over the Northern Pennines is due to a covered acid intrusion, from which originated the mineralization of the area. The negative anomaly is caused by direct density contrast between acid intrusive and denser country rock.

(2) The negative anomaly must be produced by a total removal of actual mass. For a buried acid intrusion such as the " Weardale

granite" this removal cannot have taken place upwards, as extensive metasomatism of the surface rocks is not observed, apart from the vicinity of mineral veins. Sideways migration is precluded as there is no surrounding ring of large enough positive anomaly. Hence there must be a net downward movement of mass. This is strong evidence for the magmatic origin of the intrusion and conflicts with any granitization theory as now presented.

Negative anomalies over exposed granites may also point to their magmatic origin by bulk downward removal of denser material (stoping), particularly when the intrusive relations are such as to exclude the possibility of granitization of a less dense lithological phase, which may well occur during earth movements (syn-tectonic).

(3) Downward removal of denser material, to be replaced by rise from below of less dense material, will result is a dissipation of gravitational and perhaps elastic energy as heat. For a resultant density change of $-0{\cdot}2$ gms./c.c., with downward movement of 20,000 feet, at least one calory per gramme of original rock will be liberated, and this may contribute slightly to the production of heat for "melting a magma", although quite clearly it cannot be the sole source of heat.

(4) The full structural implications have not yet been studied, but it is apparent that the intrusion may have dominated subsequent faulting, in particular of the Ninety Fathom Dyke.

IV. Acknowledgments

We wish to thank Mr. B. C. Browne for his loan of instruments and advice in planning, Dr. R. I. B. Cooper for demonstrating the gravimeter, Professor W. B. R. King, from whose department the work has been done, Professor Westoll, Professor Dunham, and Dr. Nockolds for helpful advice, Mr. J. Hospers and Dr. P. L. Willmore for showing us the manuscript of their paper, and Mr. W. B. Harland, who supervised the work. One of us (M. H. P. B.) is grateful to the D.S.I.R. for a maintenance grant.

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On the thecae of *Monograptus scanicus* Tullberg

By O. M. B. Bulman

Abstract

Monograptus scanicus is shown to possess thecae which terminate in a pair of laterally-placed, expanded lappets ; these are elongate-ovoid in shape, set with their long axes at right-angles to the axis of the theca.

Introduction

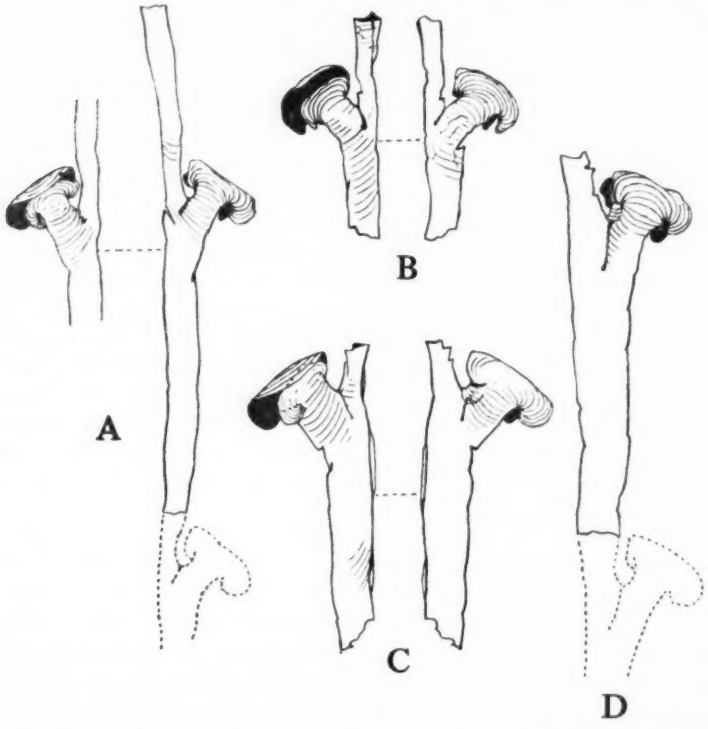
THE writer has recently received from Dr.W. G. Kühne specimens of monograptids obtained by dissolving limestone boulders collected from the Pleistocene deposits of the North German Plain around Berlin. These boulders are evidently of Lower Ludlow age, and the graptolites obtained included *Monograptus chimaera* and var *salweyi*, *M. dubius*, *M. nilssoni*, *M. bohemicus* and several retiolitids. They correspond with an association represented on several unpublished plates illustrating the Holm Collection at the Riksmuseum, Stockholm, which was obtained from boulders at Rostock, Hamburg, and at Aarhus (Denmark) ; and earlier still a generally similar assemblage was described by Heidenhain (1869). Also among these species was the form illustrated in Text-figs. 1 and 2 below (and again in the Holm Collection plates) which gave some difficulty in its identification. This had much the appearance of *Monograptus scanicus* Tullberg 1883 ; but *M. scanicus* has always been regarded as a form with hooked—almost clawed—thecae : it was so described by Tullberg (1883, p. 26) and was included in Group IV of the monograptids by Lapworth, Elles and Wood (1913, p 433) : whereas the form under consideration possesses straight thecae with very characteristic paired and expanded lappets. Examination of well-preserved *M. scanicus* material in shale (including the original of Lapworth, Elles, and Wood, pl. xliv, fig. 2c [1]) indicates that this hooked appearance is deceptive, and that the thecae are in fact provided with lateral apertural processes exactly like those of this Baltic Drift material. There can be little doubt that the Baltic material is *M. scanicus* and it may be noted that Tullberg includes in his synonymy the species from the " Diluvialgeschiebe der norddeutschen Ebene " described by Heidenhain (1869, p. 147 and pl. 1, fig. 1) as *M. distans* Portlock. On the basis of this limestone material, the thecal structure of *M. scanicus* can now be more accurately described.

Description

All available fragments are small and the largest is not more than a few millimetres in length ; proximally, where the rhabdosome is

[1] I am indebted to Professor Shotton and Dr. Isles Strachan for the loan of this and other specimens from the Geology Department at Birmingham.

extremely tenuous, it is so broken that only single thecae occur, but associations of two or three together of the more distal thecae are present. The fragments were successfully cleared with concentrated nitric acid and potassium chlorate ; growth lines are well displayed on

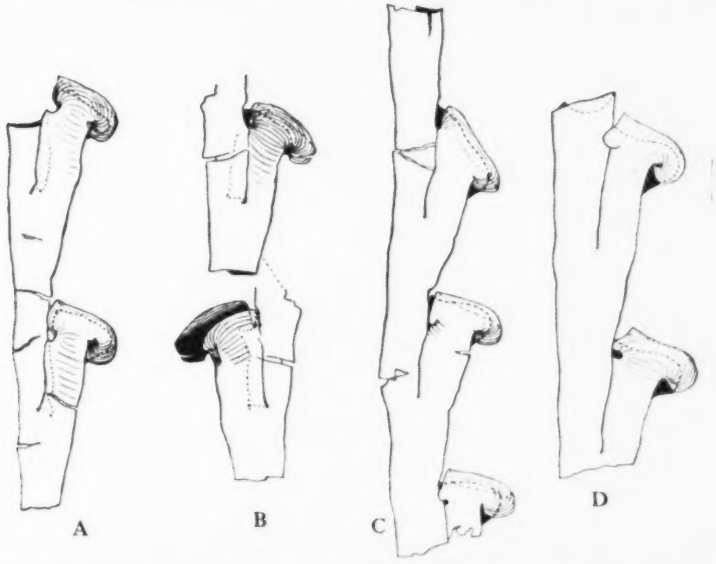


TEXT-FIG. 1.—*Monograptus scanicus* Tullberg ; Lower Ludlow boulder, near Berlin. Four thecae from proximal end (A, SM A 24307 ; B, SM A 24308 ; C, SM A 24309 ; D, SM A 24310) arranged in order of size (diameter) and showing increasing overlap. The smaller lappet is seen in the left-hand views of A, B and C. Growth lines drawn by transmitted light, but omitted for clarity from the lappet at the back in each figure. All × 30 approx.

the lappets and generally more or less visible on the distal parts of the thecae, but practically no trace was to be seen on the prothecal portion (except that illustrated in Text-fig. 1B).

Proximal thecae. These consist of slender tubes with practically no overlap and a prothecal ratio of about 90 per cent (excluding the apertural processes in the calculation) ; probably this ratio is practically 100 per cent initially, and the value decreases steadily throughout the rhabdosome.

In the earliest theca represented in this collection (Text-fig. 1A) the prothecal portion begins as an extremely slender tube (less than 0·1 mm.), then widens slightly and remains nearly constant at 0·13 mm. throughout most of its length, and distally widens again just before it merges into the true thecal portion. The whole theca has an estimated length of 1·75 mm., of which the prothecal portion represents the proximal 1·6 mm. and the true thecal portion 0·15 mm. The true theca is a straight cylindrical tube 0·14 mm. wide, of which the distal



TEXT-FIG. 2.—*Monograptus scanicus* Tullberg; Lower Ludlow boulder, near Berlin. Four specimens from (probably) central part of rhabdosome (A, SM A 24311; B, SM A 24312; C, SM A 24313; D, SM A 24314) arranged in order of increasing overlap, showing mainly the characters of the larger (right-hand) lappet and the reduction and loss of isolation of the distal part of the theca. 2B shows the mature form of the smaller lappet. Growth lines, and interthecal septa in A and B, inserted by transmitted light. All × 18 approx.

half is isolate; this terminates in a pair of laterally placed, expanded lappets. These are strongly convex, elongate-ovoid, with their long axes at right-angles to the axis of the theca; and their development is well shown by the growth-lines. It may be remarked that they are never quite symmetrical in any theca, one of them (left-handed to the zooid in all my specimens) being appreciably smaller than the other. Both curve in over the aperture of the theca and the smaller one is distally overlapped by the larger (Text-figs. 1A, C, 2B).

Distal thecae. Judging from shale material of *M. scanicus* none of the isolated fragments include any really distal thecae and the observations below relate to thecae from the more central part of the rhabdosome.

Traced distally, the thecae, as already remarked, show a progressively greater overlap and a considerable increase in size. Among fragments preserved, the prothecal ratio falls to 65 per cent (Text-fig. 2D) in a theca 2·2 mm. in length with protheca 1·5 mm.; the width of the true theca is 0·3 mm. At the same time, they lose the isolate distal end, becoming adnate throughout. The asymmetry of the lappets, already noticed, appears to become progressively greater as the thecae are traced distally. The larger (right-hand) has generally similar characters to those described above, but becomes more strongly convex and more completely overhangs the aperture; while the smaller (left-hand) sometimes shows a tendency (Text-fig. 2B) to fuse on the ventral side with the wall of the theca.

Preservational Appearances in Shale Material

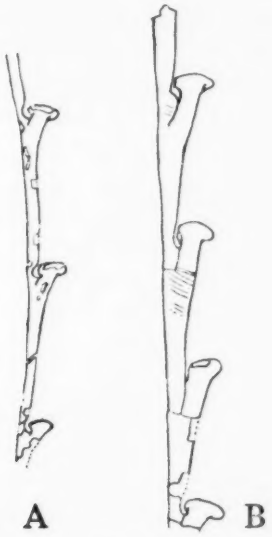
It is scarcely to be expected that such lappets will be exactly constant in actual shape (outline, convexity, and " set " on the theca), and their variation is likely to be considerable where they are compressed, partially abraded, or partially concealed by matrix. Preserved in true profile view, it will be seen that (particularly in distal thecae, Text-fig. 2D) they might closely simulate a hooked theca; whilst a strongly convex lappet slightly abraded would give a conspicuously clawed appearance. The obverse view (theca facing left, with the smaller lappet exposed and the larger covered by matrix) might easily pass for an almost unmodified straight theca. Partial concealment and slight abrasion also presents numerous possibilities as concerns the proximal thecae, but the two views (left and right) are likely to be more generally similar and to give a predominantly hooked appearance. It is possible that badly preserved examples, where the lappets were completely flattened, might simulate compressed lobate thecae.

Other Comparable Thecae

It is probable that a generally similar type of theca occurs in *Monograptus crinitus* Wood, but no really well-preserved examples of this species seem to be extant; even the figured specimens (Lapworth, Elles, and Wood, 1913, pl. xliv, fig. 3), preserved at Birmingham University, are abraded and difficult to interpret. It seems not unlikely, however, that the " *Monograptus* sp." from the Holm Collection figured in Bulman, 1938, fig. 20c, is referable to *M. crinitus*.

Less closely allied are the " gedeckelten " monograptids described

by Münch (1938) under the names *Barrandeograptus operculatus* and *B. huckei*, and by Eisenack (1942) as *Monograptus aversus*. These have the thecal aperture covered by a flat, almost circular lid or shield apparently developed from the dorsal margin of a slightly isolate theca. That it is an unpaired structure is indicated by the zig-zag growth-lines down its mid-line (Münch, pl. 8, fig. 4). However, the proximal thecae



TEXT-FIG. 3.—*Monograptus scanicus* Tullberg; Lower Ludlow, Elton–Ludlow road, near Ludlow. A, proximal (cf. Text-fig. 1A) and B, more distal thecae (cf. Text-fig. 1D) of the specimen (itself a proximal fragment) figured by Lapworth, Elles & Wood, 1913, pl. xliv, fig. 2c. Geological Department, Birmingham University. × 15 approx.

attributed by Eisenack to *M. aversus* (pl. 2, fig. 8) are so different from the distal thecae (pl. 2, fig. 1) of that species that it is hard to accept them as the same form. Whereas the distal thecae are covered by a nearly circular shield produced from the dorsal margin, these proximal thecae exhibit a laterally-produced shield which superfically at least is exactly like the *scanicus* thecae shown here in Text-fig. 1. Only one view is given by Eisenack and the drawing is not particularly well reproduced, so that one cannot determine whether this is a paired lappet structure, but I believe the specimen may well be the proximal end of *M. scanicus*. If this is so, however, the left-hand lappets are here the larger, contrary to the condition in the material under examination.

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THE SEDGWICK MUSEUM,
CAMBRIDGE.

The Editors have been requested by Dr. Hallimond, through his Solicitors, to include in this issue of the *Geological Magazine* as an ordinary article the following comments upon the article by Mr. C. R. K. Blundell published in the Jan.–Feb. (1953) number.

Magnetometric Mapping for Haematite in South Wales

Comments on Mr. C. R. K. Blundell's Paper (*Geol. Mag.*, vol. xc, p. 57).

MR. BLUNDELL'S account of earlier work by A. F. Hallimond and J. T. Whetton (*Bull. Geol. Surv.* No. 2., pp 1–17, 1939) is inaccurate in certain particulars and is liable to mislead.

(1) Blundell (p. 57) "*The only correction applied to the field observations seems to have been that for the diurnal variation*".

Hallimond and Whetton (pp. 14–16) do, in fact, give a very full discussion of regional and other corrections, with the conclusion (p. 16):

"This is confirmed, in the direction at right angles, by the level values at the corresponding end of the other traverses: small local effects are present but the general level falls only slightly from 20 gamma to about 14 gamma in the extreme north."

"It is permissible, therefore, to assume that the base surface is practically level at from 14–20 gamma and that the observed anomalies can be assigned to local ore-bodies without correction other than allowance for a slight northward fall in intensity."

(2) Blundell (p. 57) "*The results of such surveys have usually been inconclusive and have not led to the discovery of any large new ore-bodies.*"

Hallimond and Whetton (p. 17) reported as follows:

"The local results may be summarized as follows. Trials with a vertical magnetic field balance were made over an elongated body of haematite ore, known to have a cross section of about 50 ft., a depth of 100 ft., and a cover of about 60 ft. of boulder clay, situated near Red Hill Farm, Millom, Cumberland. An anomaly of about 30 gamma was observed (see Section II). Using precise methods, a detailed magnetic survey was then made of a neighbouring area about 1,000 ft. square (see Section III). A parallel elongated anomaly was located, similar to that found in the first trials, and this is associated with an ore-body, which, so far as it has been explored, is closely comparable with its previously known neighbour."

(3) Blundell (p. 60). "*Hallimond and Whetton* (1939, *p.* 17) *pointed out that in the case of the Cumberland area, the anomalies due to the*

haematite were only of the same order of magnitude as those caused by boulders in the glacial drift. In order to overcome any ambiguity due to this . . . the conventional practice of . . . linear traverses was abandoned."

Hallimond and Whetton showed, in fact, that the effect of boulders at Millom was far less than the anomaly observed :

(p. 17) " (2) The anomaly, being small, is comparable with those due to buried objects such as large boulders in boulder clay, or to magnetic country rocks. In every case such possibilities must be borne in mind ; not only the size, but the distinctive form of the anomaly must be shown to correspond with that to be expected for the ore-body whose presence is deduced."

(p. 14) " Only a large or very magnetic boulder would produce a measurable effect from, say, 30 ft. deep, and in the present ground such boulders are rare or completely absent. Any disturbance from superficial objects will therefore originate in the immediate surface layer ; it will thus be limited in lateral extent to a radius comparable with the depth and is unlikely to affect more than two stations if these are, say, 20 ft. apart. Small boulders, or cobbles, are common here in the boulder clay, and there will be always the risk of an error of perhaps one or two gamma if the instrument happens to be directly above a concealed boulder."

(p. 13). " The profiles exhibit . . . (2) a very pronounced anomaly of ridge-like form with its crest roughly parallel with, and about 200 ft. distant from, the farm road."

Also, Fig. 8 shows those profiles rising to form an anomaly more than 20 gamma high, with a width at half-height equal to more than 100 feet (the cover was up to 50 ft. of boulder clay).

(4) Blundell (p. 60) claims that " *the conventional practice of . . . linear traverses was abandoned. Instead, the results were expressed directly on the map by means of contours showing the magnetic residuals in the area. In this way, although the actual intensity of the anomaly produced by a small object at shallow depth may be similar to that due to a larger but deeper mass, the areal distribution of the anomaly as shown by the magnetic contours at the surface serves to distinguish between the two causes.*" Similar claims are made elsewhere, and are a leading feature of the paper. In fact, the distribution of stations in a network, and the use of a regional correction (if it can be ascertained) have been the normal practice in magnetic surveying ever since field variometers came into use. Profiles along traverses (like geological vertical sections) are used in the closer appraisal of an area.

In special cases, where the geology is already well-known (e.g. in precisely locating a dyke or fault of known strike) it is economical to omit the network and to make one or more traverses at right angles to a

known linear feature (e.g. in tracing the extension of the Swynnerton dyke or the outcrop of the Whin Sill). This was the case at Millom (see " Geology " and " Orebodies " in H. and W. pp. 12 and 13) and in nearly all the magnetic investigations made by the Geological Survey.

In irregular ground (like the South Wales area) the network is obviously required, but it is not a new method and it in no way supersedes the use of traverses. Mr. Blundell's survey (fig. 4) revealed a positive area of round shape. If subsequent work should lead to an elongated anomaly, the usual procedure of making closely determined traverses, with comparison of the profiles with those calculated for the proposed geological structure, could be followed with advantage. Neither the use of a network nor the application of a regional correction is new.

A. F. HALLIMOND.

J. T. WHETTON.

CORRESPONDENCE

MAGNETOMETRIC MAPPING FOR HAEMATITE IN SOUTH WALES

SIR,—C. R. K. Blundell's paper on magnetometric mapping for haematite in South Wales (*Geol. Mag.*, xc, 57–64) is to be welcomed, but his interpretation of two of the anomalous areas is erroneous.

He explains the residual Low anomaly A1 (Text-fig. 3) as part of the field due to the main Llanharry ore-body. His iso-magnetic contours are evidently not shown in full, but those depicted in the area A1 are too closely spaced to be connected with the anomalies at A. If a profile of anomalies is drawn across A and A1 it is easily seen that the A1 Low must be due to a separate body of little depth, probably not connected at all with the main body of haematite at A.

The same is true of the High at B and the Low at B1 ; these two anomalies are too far apart and too " sharp " to be assigned to the same ore-body, though of course there might be a connection between any of these bodies at a considerable depth. In no way can the anomalies at A1 and B1 be explained as he suggests in his Text-fig. 2.

An alternative explanation is that these Lows A1 and B1, and possibly some of the other Lows as well, may be due to ore-bodies " reversely " magnetized, that is possessing a residual magnetism derived from a former reversed earth's field. Such reversals of the field have been a frequent feature of the earth's magnetic history. If this is the case the extensive anomaly of + 5 gamma, shown in the right half of Text-fig. 4 may very well be associated with the Lows to the north of it.

There should be a good chance of detecting an ore-body under A1 or B1 by sensitive gravity measurements, as bodies giving rise to these anomalies of − 15 to − 20 gamma should produce a gravity anomaly of perhaps 0·3–0·5 milligals.

C. D. V. WILSON.

THE JANE HERDMAN LABORATORIES OF GEOLOGY.
UNIVERSITY OF LIVERPOOL.
7th February, 1953.

SIR,—I was pleased to see Dr. C. D. V. Wilson's pertinent remarks on my paper. The alternative interpretations which he advances were carefully considered, together with some other possibilities, during the late stages of the survey and they continue to be borne in mind as further work continues.

Briefly, most of the possible explanations revolve around the question of whether or not the relationships between the main ore-body, the High A and the Low A1 are fortuitous. Dr. Wilson suggests that this may be the case as far as the Low A1 is concerned, and he interprets this Low as being due to a separate ore-body.

In the absence of other evidence to indicate the possibility of a deposit of haematite occurring just south of Llanharry, it was decided to advance the more cautious and conservative interpretation given in the paper. Thus, whilst Dr. Wilson's remarks might imply the occurrence of three new ore-bodies, the tentative interpretation put forward in the paper suggests the presence of only one large new body.

If the Low A1 is regarded as being due to the main ore-body, one of the major factors governing its position and value is the effective shape of the uppermost part of the deposit. The kinds of shapes involved are illustrated in Sibly's work, which is quoted in the paper. The idealized geometrical shape shown in Text-fig. 2 is merely a diagrammatic aid to illustrate in a qualitative way the principles involved. Until the evidence of boreholes in the area is available any more rigorous analysis of the results would be misleading if

not actually dangerous. Similarly, major assumptions regarding direction of polarization are to be avoided at this stage.

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3rd March, 1953.

THE STONE OF THE ANCIENT ASSYRIAN MONUMENTAL CARVINGS

SIR,—Thirty years ago there appeared in the *Geological Magazine* (lix, 1922, 222–3) a short paper by Dr. Hans Reusch, formerly Director of the Geological Survey of Norway, concerning the Assyrian carved monuments in the British Museum and in particular the winged human-headed lions from the palace of Sargon II at Khorsabad which now stand in the entrance to the Assyrian Galleries. Dr. Reusch described the stone in which these monuments are carved as a " quartz-eyed-gneiss ", i.e. a metamorphosed conglomerate, a type of rock with which he was familiar in Norway and which he had described from the Ordovician of the neighbourhood of Bergen.

In fact, the stone in question contains no quartz, the mineral which occurs so abundantly in large fragments in the Sargon lions and bulls being gypsum.

The rock is the so-called " Mosul Marble " which was much used as a monumental stone by the Assyrian kings under the name of *pilu* or *parutu* and which is still much used for architectural purposes in Mosul at the present day. It is gypsum of Miocene age, passing into anhydrite at depth as seen in the deeper quarries and in cores, which is well-bedded in parts but in some beds exhibits a striking brecciation owing to some diagenetic effect. Reusch also described small, closely folded granitic veins traversing the rock ; these are no doubt films of gypsum showing the folding which frequently results from the increase in volume associated with the change from anhydrite to gypsum.

Specimens of the mineral fragments and also of the apparently argillaceous matrix were examined optically, chemically, and by X-ray powder photography and found to be gypsum. It can be stated therefore that the sculptures are made entirely of gypsum.

We are indebted for help and information to Dr. C. J. Gadd, Keeper of the Department of Egyptian and Assyrian Antiquities at the British Museum, and to Dr. F. R. S. Henson of the Iraq Petroleum Company.

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26th January, 1953.

REVIEW

THE GEOLOGICAL SURVEY OF GREAT BRITAIN. By Sir EDWARD BAILEY. pp. xii + 278, with 4 pls. and 39 text-figs. Thomas Murby and Co. (George Allen and Unwin). 1952. Price 22*s.* 6*d.*

The first hundred years of the Geological Survey of Great Britain was an official history compiled by Sir John Flett (Director, 1920–35), in connection with the centenary celebrations of the Survey in 1935, and was published in 1937.

The appearance of another book on the Geological Survey which covers much the same ground is explained in the Preface. It was prepared for a series called *Science in Britain* to be issued by the British Council, but the publication of that series was suspended before the manuscript was ready.

The book has necessarily much in common with the official history since it deals with internal matters such as the production and publication of maps and memoirs, which are the main purpose of the Survey. It follows also the same plan in dividing up the period according to the " reigns " of the various Directors-General (as they were until 1901), ending with that of the author as Director in 1945.

It reads rather like a series of essays written around each Director, highlighting the main geological events which were characteristic of each reign, and as such will be found entertaining by geological readers outside the Survey. Space only allows brief references to these.

Under Sir Henry de la Beche (1835–55) are naturally chronicled the events which led to the establishment of a Geological Survey, at first on a very tentative basis. It is evident that Geological Surveys in all parts of the British Isles owe a great deal to the inspiration and encouragement of Captain (later Major-General) T. F. Colby, who was in charge of the Ordnance Survey from 1826 to 1846.

In 1832 de la Beche was appointed to affix geological colours on the one-inch-to-the-mile Ordnance Survey maps of south-west England which were then being published. It is worth noting that each of these sheets covered an area of over 960 square miles, but it is recorded that before 1835 four of them were published with geological colours, three others were complete, and an eighth was nearly finished ! Parts of these areas have never been resurveyed. It is no wonder that such amazing results were followed in 1835 by a general permission to colour geologically the Ordnance County maps and the selection of de la Beche to organize the work. Thus was established the Geological Survey of Great Britain.

de la Beche proved to be what would nowadays be described as an " empire builder ", and very shortly a geological museum came into being and seven field geologists with two palaeontologists were appointed on his staff, thus firmly consolidating the service and laying down the broad lines of its organization. It is interesting to recall that up to 1846 geologists were required to wear a blue uniform in the field with brass buttons and a top hat !

Although the second Director-General, Sir Roderick Murchison (1855–71), was 63 years of age when he was appointed, he was in charge until he died at 79 years of age. His fame among foreign geologists brought great distinction to the Survey. It was a period of expansion of the staff and of active field mapping. The general organization of the field staffs were laid down, which has survived in more or less modified form to the present day. He was succeeded by Sir Andrew Ramsay (1872–81) who, starting under de la Beche, had been a field geologist for over thirty years when he was appointed Director-General. It is probably to him more than to any individual geologist that we owe the great tradition of geological mapping which made the Survey so famous. This tradition, with some improvements dictated by experience, has been handed down largely by oral instruction to the modern generation.

It was also a period of great activity, and an extraordinary number of geological maps both on the six-inch and on the one-inch scale were issued,

but as might be expected the publication of corresponding memoirs failed to keep pace, and sheet memoirs of many one-inch maps have never appeared.

So great was the progress in field surveying in Ramsay's day that his successor as Director-General, Sir Archibald Geikie (1882–1901), could look forward to the completion of the geological mapping of the British Isles on the one-inch scale during his tenure of office. In his last year, however, a Royal Commission was set up under the Rt. Hon. J. L. Wharton to inquire into the organization of the Survey and other matters. One of the recommendations of the Commission was that the completion of the primary geological survey on the scale of six inches to the mile should be made the first duty of the Survey. This, of course, gave the Geological Survey a new lease of life.

One of the noteworthy events of the period was the storm that broke over Geikie in his first years, as a result of which the geological succession which was set up by Murchison in the north-west Highlands and defended against all critics had to be abandoned. The author, in laying a good deal of stress on the part played by Callaway in that famous controversy, scarcely does full justice to Lapworth.

The detailed lithological succession published by Lapworth in the *Geological Magazine* for 1883 anticipated the subdivisions of the quartzites and Durness Limestone which were subsequently used by Peach and Horne in working out the structure. There is no doubt that Lapworth had solved the main secrets of the area before Peach and Horne set foot on the ground, but Geikie took care that the credit should fall to the Survey, and Lapworth's name was not even mentioned in his preliminary report.

Sir Jethro Teall (1901–14), who was appointed on the resignation of Geikie, was, in accordance with one of the recommendations of the Wharton Committee, styled Director. Teall was an enthusiast and his reign was a very happy one for the staff apart from the very low salaries that prevailed. It is notable that the term Ordovician was introduced into Survey literature for the first time in Teall's first annual report. Was it Hughes or de Lapparent who made the remark about Lapworth and the oyster ?

Sir Aubrey Strahan (1914–20), who followed him, had hardly got into the saddle when war broke out. One of the most memorable results of his period is the series of Special Reports on the Mineral Resources of Great Britain which were got together with remarkable speed to furnish information on various economic products required during the war and after.

The author thinks that " the 1914 War was a comparatively happy one for juniors on the staff " [!].

When Strahan retired after the end of the war he was succeeded by Sir John Flett (1920–35). There is no doubt that the most important geological event of his " reign " was the building of the new museum and offices at South Kensington and the move in 1934 from the old premises in Jermyn Street which had been the home of the Survey's various activities since 1851. It is pleasant to record that the author warmly expresses a " feeling of gratitude to Flett, to whom above all, with the whole-hearted support of his colleagues, the nation owes this great achievement ". It is regrettable therefore that he has allowed himself to make the reference to Flett's deafness which appears on another page. Flett was as keenly aware of what went on around him as anybody and most people who knew him felt that if his deafness was an affliction he turned it to very good use.

Flett's successor, Bernard Smith (1935–6), died within less than a year of taking up his appointment as Director, and the author (1937–45) was appointed after a short interregnum.

The book closes with an account of Bailey's stewardship. Only a short period intervened before war broke out in 1939, and the museum became the headquarters of the London Civil Defence Region. As in the previous war, the Survey turned to the task of providing information on a great variety of materials of economic importance and thus were initiated the multigraphed special reports known as Wartime Pamphlets. About half of these (forty-eight) dealt with water supplies, but others embraced a great variety

of economic products, including such diverse materials as mica, glauconite, ochre, and peat. These proved extremely useful and Bailey's " reign " will always be associated with their production. Some of the line drawings, notably Fig. 21, are somewhat woolly, and a few misprints have escaped the proof-reader's eye.

O. T. J.

PUBLICATIONS RECEIVED

Geological Survey of Canada : Publications of the Geological Survey of Canada (1917–1952), compiled by Lorne B. Leafloor. 82 pp., 1952. Price 50 cents.

Geological Survey of Canada : Memoir 264. Carboniferous Stratigraphy and Palaeontology in the Mount Greenock Area, Alberta. By R. A. C. Brown. 119 pp., with 5 plates and 16 text-figures. Ottawa, 1952. Price 75 cents.

Geological Survey of Canada : Memoir 265. Torbay Map Area, Newfoundland. By E. R. Rose. 64 pp., with 5 plates, 5 text-figs., and coloured map in pocket. Ottawa, 1952. Price 75 cents.

Geological Survey of Canada : Bulletin 21. Ammonite Faunas of the Upper Cretaceous Rocks of Vancouver Island, British Columbia. By J. L. Usher. 182 pp., with 32 plates and 4 text-figs. Ottawa, 1952. Price $1.

Geological Survey of Canada : Bulletin 22. Deep Wells and Subsurface Stratigraphy of part of the St. Lawrence Lowlands, Quebec. By Helen R. Belyea. 113 pp., with 1 plate and 4 figs. Ottawa, 1952. Price 50 cents.

Annales de la Société géologique de Pologne (*Rocznik Polskiego Towarzystwa Geologicznego*), xxi, fasc. 3, 1951 (1952), 279–336. (Comprising : Geological investigations in the northern part of the Intra-Sudetian Trough : Upper Devonian and diabases in the locality Strumik : Remarques sur certain représentants de la faune boréale dans le Jurassique de Cracovie-Czestochowa : The Ophiolite from Osielec : Remarks on the Pleistocene in the Lower Vistula area : each with a summary in the language indicated.) Cracow, 1952 (no price).

Speleon : Revista Espanola de Hidrologia, Morfologie Carstica y Espeleologia. Tom. 3, nos. 3 and 4. 1952. (Instituto de Geologia, Oviedo.)

Waterberg Coalfield : Records of bore-holes 41–100 drilled for the Department of Mines. *Union of South Africa, Dept. of Mines ; Geological Series, Bull.* 21. 381 pp., with columnar sections and folding map. Pretoria, 1951, price 7*s.* 6*d.*

Liverpool and Manchester Geological Journal. Vol. i, pt. 2, 1952 (1953). pp. 148–219 + vi–x (Liverpool Geological Society, price 10*s.* 6*d.*).

F. E. Zeuner. *Dating the Past : An Introduction to Geochronology.* 3rd edn. (revised), pp. xx + 495, with 24 pls. and 101 text-figs. Methuen and Co., Ltd., 1952, price 42*s.*

V. C. Kelley and C. Silver. Geology of the Caballo Mountains. 286 pp., with 19 plates and 26 figs. (including folding maps in pocket). University of New Mexico, Geol. Publ. no. 4. 1952. Price $5.

Alfred Blanchet. Oiseaux de Tunisie : 1, Région de Sousse et Sahel. *Mémoires de la Société des Sciences Naturelles de Tunisie*, 1, fasc. 1er, 1951. 4to, pp. ix + 92 + 15, with xiii collotype pls. No price.

SWIFT PETROLOGICAL MICROSCOPE. Triplecentring Nosepiece. Iris Diaphragm. Condenser. Camera Lucida &c. 1951 Model. Unused. Cost £70 10s. Accept 55 gns.—LOWE, 2 Stuart Ave., London, W. 5.

WANTED. Geological Magazine, Vol. 83, No. 1 (or complete volume). Geology Department, University of Otago, Dunedin, New Zealand.

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